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ONTARIO PESTICIDES ADVISORY COMMITTEE

RESEARCH PROJECTS

FUNDED BY

THE MINISTRY OF THE ENVIRONMENT

1990 - 1991

The Ontario
Pesticides
Advisory Committee

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MINISTRY OF THE ENVIRONMENT
AUG 12 1991
HAZARDOUS CONTAMINANTS
BRANCH

ISSN 1183-2177

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PESTICIDES ADVISORY COMMITTEE

1990-91

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RESEARCH PROJECTS FUNDED BY THE MINISTRY OF THE ENVIRONMENT THROUGH THE ONTARIO PESTICIDES ADVISORY COMMITTEE, 1989-90

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EXECUTIVE SUMMARY

1. In 1990-91, the Ontario Pesticides Advisory Committee continued a program, begun in 1973, of funding research on environmentally acceptable pest control procedures. The 1990-91 research program focused on:

   (a) Developing biocontrol agents to replace sythetic chemical pesticides.

   (b) Improving weed and insect control technique with reduced herbicide and insecticide inputs.

   (c) Reducing residues in water and food.

   (d) Reducing human exposure to herbicdes.

2. The research budget was $ 400,000.

3. Fifty-one research proposals totalling $ 938,460 were received.

4. Twenty-five proposals were funded for a total value of $ 388,139. Awards averaged $ 15,525 and ranged from $ 6,000 to $ 40,000.

5. Fifteen grants totalling $ 249,255 were awarded for studies focusing on the development of biological agents for the reduction of pesticide input.

   Summary

	Plant/Crop	Pest Problem	Biocontrol Agent	Main Researcher
1.	Deciduous Trees	Gypsy Moth	Virus	Cunningham
2.	Deciduous Trees	Gypsy Moth	Insect Parasites	Nealis
3.	Conifers	Spruce Budworm	Fungi & Insects	Van Frankenhuyzen
4.	Tobacco	Nematodes	Brassica Extracts	Brandle
5.	Apples	Codling Moth	Virus	Jaques
6.	Conifers	Flies	Traps	Turgeon
7.	Curumden	Powdery Mildew	Fungi	Jarvis
8.	Nursery Stock	Root weevil	Nematodes	Smith
9.	Strawberry	Gray mould	Fungi	Sutton
10.	Coniferous trees	Spruce Budworm	Bacteria	Bendell
11.	Home Gardens	Insects	Plants/culture	McLeod
12.	Apples	Scab	Plant oils	Northover
13.	Turf	Weeds	nitrogen	Hall
14.	Corn	Weeds	management	Hofstra
15.	Corn	corn rootworm	crop insurance	Stemeroff

6. Five grants totalling $ 61,000 were allocated for studies focusing on reducing pesticide inputs into the environment and reducing human exposure.

Summary

	Plant/Crop	Pest	Pesticide	Technique	Main Researcher
1.	Conifers	Deciduous Trees	Glyphosate	Reduced use	Hofstra
2.	White Beans	Ragweed	Herbicides	Banded	Swanton
3.	Onions	Weeds	Herbicides	Barley	Souza Machado
4.	Row Crops	soil/insects	Insecticides	New technology	Schaafsma
5.	Row Crops	insects	Insecticides	P-glycoprotein	Morris

7. Five grants totaling $ 77,884 studied pesticide residues in the environment and food.

Summary

	Environment Component	Pesticide	Indicator	Main Researcher
1.	Stream Water	Atrazine/Metolachlor	Algae	Day
2.	Algae Fibrils	Fenvalerate/PCP	Aquatic Organisms	Kaushik
3.	Soil	Herbicides	Soil Microbiota	Tomlin
4.	Water	Pesticides	Immuno Assay	Hall
5.	Turf	fungicides	Bioassay	Hsiang

8. The Ontario Pesticides Advisory Committee is satisfied with the research progress in 1990-91. It recognizes that, with the funds available, the program can be expected to act only as a catalyst in stimulating support by other interested agencies for urgently required research in the broad areas indicated in the Committee's guidelines.

9. The Ontario Pesticides Advisory Committee recommends that the Ministry of the Environment continue to support the OPAC research program and OPAC liaison activities ensuring financial accountability.

I. OBJECTIVES

The Ontario Ministry of the Environment first allocated funds to the Ontario Pesticides Advisory Committee (OPAC) to sponsor pesticide-related research in 1973. Terms of Reference developed by OPAC in 1990-91 to govern the awarding of research grants focused on:

1) Ways of reducing inputs of pesticides into the environment.

2) Minimizing risks from pesticides to the environment and human health.

3) Enhancing the effectiveness of pest management practices.

An announcement inviting research proposals in several specific areas relating to the program objectives is reviewed and revised annually by OPAC in consultation with the Ministry of Environment Research Advisory Committee. In 1990-91, research proposals were invited in twelve specific areas relating to the three research objectives (Appendix I).

II. SELECTION PROCEDURE

Notices inviting applications for research support were widely distributed in November, 1989 through January, 1990 to researchers and administrators in Ontario universities, industry, government, and other organizations, with deadlines for receipt of applications being January 29, 1990.

During the first three weeks in February, members of the Research Subcommittee and selected reviewers appraised the submissions and ranked the proposals in three categories: fund, not fund, reconsider with changes. The reviewers were chosen for their broad knowledge of pesticides and expertise in pest control.

Criteria used in judging the applications included:

1) the degree to which the proposal fits the guidelines
2) the importance of the problem that the proposal addresses
3) the anticipated application of the results of the proposed work
4) the probability of achieving the stated objectives
5) the experimental design of the proposal
6) the technical merit of the proposal
7) the competence of the investigators
8) the suitability of the facilities available for the study
9) the adequacy of the budget

Recommendations prepared by the Research Subcommittee were reviewed by OPAC in February, 1990. OPAC recommendations were then forwarded to the Ontario Ministry of Environment's Research Advisory Committee for confirmation and funding. Funds were made available to most grant recipients by mid May.

III. PROJECTS SUPPORTED

The OPAC research budget in 1990-91 was $ 400,000.

Fifty-one research proposals totalling $ 938,460 were received. Most were from universities/colleges (Brock, Guelph, McMaster, Ridgetown College of Agricultural Technology, Sault College of Applied Arts and Technology, Toronto, Waterloo, Ottawa and Western). The remaining applications were from industry or other organizations.

Twenty-five proposals were supported (Appendix II). Awards averaged $ 15,525 (range $ 6,000 to $ 40,000). Disbursement of research funds by organization is summarized below:

Organization	No. of Grants	$ Total of Grants
Ridgetown College of Agricultural Technology	1	6,000
Sault College of Applied Technology	1	16,000
University of Guelph	10	144,167
University of Toronto	4	56,700
University of Western Ontario	2	32,684
University of Ottawa	1	20,000
Other	6	112,788
TOTAL	**25**	**388,139**

Results obtained in the various studies are summarized in Appendix III.

Fifteen grants totalling $ 249,255 were awarded for studies focusing on the development of biological agents for the reduction of pesticides input.

Five grants totalling $ 61,000 were allocated for studies focusing on minimizing risks from pesticides to the environment and human.

Five grants totalling $ 77,884 studied pesticide residues in the environment.

IV. ACCOUNTABILITY

Direction and progress of the research were monitored by OPAC in several ways. Initially, some applicants were asked to modify their proposals to better meet the research guidelines. Informal contacts with OPAC members and grant recipients were established and maintained throughout the year.

In January, 1991, OPAC sponsored a two day Seminar where grant recipients presented the results of their research. This meeting was attended by OPAC members and more than 100 colleagues, peers, and guests.

In addition, the recipients were asked to provide OPAC with a summary of progress (Appendix III).

Research reports, manuals, theses etc. published in 1990-91 relating to OPAC sponsored research are listed in Appendix IV.

V. RECOMMENDATIONS

OPAC is satisfied with research progress made in 1990-91. The Committee recognizes that with the funds available, the program can be expected to act only as a catalyst in stimulating support by other interested agencies for urgently required research in the broad areas indicated in the Committee's guidelines.

The Committee recommends:

1) The Ontario Ministry of the Environment continue to support this very productive research program directed towards development of pest control programs which will not pose any serious environmental hazard.

2) OPAC continue to supervise this program following the guidelines which have been developed. With its broad expertise, strong scientific background and close liaison with the scientific community, OPAC is in the unique position of being able to define research priorities and to ensure that excellent value is received for money spent.

APPENDIX I

INVITATION TO SUBMIT RESEARCH PROPOSALS
ONTARIO MINISTRY OF THE ENVIRONMENT
PESTICIDES ADVISORY COMMITTEE 1990-1991

The Ontario Ministry of the Envionment through the Pesticides Advisory Committee has funding available for the fiscal year 1990-91 to support research relating to use of pesticides in Ontario.

Research proposals should focus on:

1. Determining potential environmental hazards associated with current pesticide use.

2. Developing modified or alternative approaches to pest control in order to reduce the pesticide input into the environment.

Although no intended to constrain the scope of the proposals, the following list (not in order of priority) indicates some areas of special interest to the Committee.

1. Occurrence, persistence, degradation, mobility, and biological significance of pesticide residues in the environment.

2. Exposure of applicators and bystanders to pesticides during and/or following application and determination of acceptable re-entry intervals.

3. Economics of pest control including estimates of losses caused by pests and determination of economic thresholds of damage.

4. Development of environmentally acceptable pest control measure for pre- and post-harvest protection of food and fibre or for use in structures.

5. Improved integration of chemical, cultural, biological, and other pest control practices.

Proposals should be designed to yield useful results in a relatively short time, generally in three years or less. Funding is committed on a yearly basis but may be extended on receipt of evidence of satisfactory progress.

Although all applications for research support will be considered, the Committee does not normally fund: early stage development studies on new chemicals; routine field efficacy trials; or pest control studies for which pesticides are not currently recommended.

Applications should be made on forms available from the Pesticides Advisory Committee. Deadline for submission of proposals is **January 31, 1990** although proposals submitted later in the year will be considered, subjest to availability of funds.

Each submission will be evaluated on factors such as:

* degree to which the proposal fits the guidelines,
* importance of the problem,
* anticipated application of the results,
* probability of achieving stated objectives,
* experimental design,
* technical merit,

* competence of the investigators,
* facilities available for the study,
* adequacy of the budget,
* overall evaluation of the project.

Grant application forms are to be submitted to:

The Executive Secretary
Ontario Pesticides Advisory Committee
Ontario Ministry of the Environment
135 St. Clair Avenue West, 9th floor
Toronto, Ontario M4V 1P5

APPENDIX II

OPAC RESEARCH GRANTS, 1990-1991

Principal Researcher	Affiliation	Project Title	Granted ($)
Bendell, J.F.	U. of Toronto	Interaction among an outbreak of Jack Pine Budworm, B.t. beneficial Lepidoptera, Spruce Grouse, Amphibia, and small birds and mammals.	$16,500
Brandle, J.E.	Agriculture Canada	Sustainable alternatives to fumigation for the control of root lesion nematodes.	$ 7,800
Cunningham, J. C.	Sault College	Development of Disparvirus (gypsy moth nuclear polyhedrosis virus) as a microbial insecticide for use in Canada.	$17,738
Day, K.	U. of Guelph	The ecotoxicological impact of agricultural runoff in streams: the effects of atrazine, metolachlor and nutrient interactions on primary productivity of attached algae.	$16,000
Hall, J.C.	U. of Guelph	Detection and quantitation of triazines, 2,4-D, metolachlor, and alachlor in Ontario precipitation using ELISA and GC.	$14,000
Hall, J.C.	U. of Guelph	Non-chemical alternatives to herbicides for weed control in turf.	$7,867
Hofstra, G.	U. of Guelph	Reducing weed competition in corn through nitrogen management.	$16,100
Hofstra, G.	U. of Guelph	Reducing the rates of glyphosate to control broad-leaved trees in conifer plantations.	$10,000
Hsiang, T.H.	U. of Guelph	Bioassay agents to detect fungicide residues in turfgrass soil.	$18,200
Jaques, R.P.	Agriculture Canada,	Effectiveness of the Granulosis Virus in Management of the Codling Moth in Apple orchards and its environmental impact.	$15,000
Jarvis, W.R.	Agriculture Canada	Integration of biological control of cucumber powdery mildew into the greenhouse pest management program.	$8,500
Kaushik, N.K.	U. of Guelph	Impact of Algal fibrils on Bioavailability of Pesticides to Non-target Aquatic Organisms.	$15,000
McLeod, D.G.R.	U. of Western	Evaluation of alternate methods of pest control for home garden.	$18,000
Morris, C.	U. of Ottawa	P-Glycoprotein, a new insight into insecticide resistance.	$20,000
Nealis, V.G.G	U. of Waterloo	Hyperparasitism and strategies for the biological control of gypsy moth in Ontario.	$13,750

Principal Researcher	Affiliation	Project Title	Granted ($)
Northover, J.	Grape & Tender Fruit (Ontario) Ltd.	Organic and modified programs for the control of apple scab.	$10,000
Schaafsma, A.	R.C.A.T.	New technology for insecticide placement to control soil insects in row crops at cultivation time.	$ 6,000
Smith, S.M.	U. of Toronto	Management of the Strawberry Root Weevil in Ornamental Tree nursery Production using Entomophagous Nematodes.	$18,000
Souza Machado, V.	U. of Guelph	Integrated weed managment systems with onions on muck soils.	$16,000
Stemeroff, M.	Deloitte & Touche	Feasibility of using crop insurance as an alternative to pesticides for managing risk of corn rootworm damage in field corn production: Phase one.	$40,000
Sutton, J.C.	U. of Guelph	Biological control of grey mold in strawberries.	$22,000
Swanton, C.J.	U. of Guelph	Integrated Weed Management in White Beans.	$ 9,000
Tomlin, A.	U. of Western	Response of soil microfauna, microflora and structure to agricultural practices in corn, soybean and cereal rotations.	$14,684
Turgeon, J.J.	U. of Toronto	Development of a colour trap to detect and monitor flies, Strobilomyia spp. infesting coniferous cones in seed orchards.	$22,000
Van Frankenhuyzen, K.	Sault College	Optimization of pathogen-parasitoid interactions for integrated management of eastern spruce budworm, Choristoneura fumiferana.	$16,000
TOTAL:			$388,139.00

APPENDIX III

Bendell, J.F., R.D. James and B.L. Cadogan

Effect of *B.t.*$_{30}$ Var. *Kurstaki* on insects, small birds and mammals, amphibia, and chicks of spruce grouse.

Objective: Our objective is to assess the impact of the operational spray of *B.t.* on wildlife feeding on caterpillars in the canopy and on low shrub, herb, and ground in plantations of Jack pine near Gogama, Ontario. *B.t.*$_{30}$ Var. *Kurstaki* kills caterpillars that are a common food of many insectivores of the boreal and other forests. Our results may help mitigate negative impacts. This year (1990) is the second of the study and methods and results to March 30 are in my report of that date to OPAC. In 1989, we sprayed from the air 2, 45 ha blocks and used 2 adjacent 45 ha blocks as controls. On each block we measured populations of wildlife before and after the spray for approximately 8 weeks. Much time has been spent on the analysis of data, especially the counting of samples of insects. In 1990, we hatched and reared 45 chicks of spruce grouse under bantam hens on areas: hand sprayed with *B.t.* at 30 BIU and 2.4 l/ha, and on control areas in the 1989 forest. Chicks were watched throughout the day and weighed daily. Chicks were ranged in moving pens in glades or freely in glades. The bantams were held in boxes with large mesh wire sides. Insects were censused on the treated and untreated areas throughout the time chicks were on the range.

Results: Densities of selected song birds decreased after spraying with *B.t.* in 1989. In the north and south forests combined, percentage difference between spray and control areas, and P values were: yellow-rumped warbler -39 ($<.09$), nashville warbler -48 ($<.01$), and hermit thrush -101 ($<.001$). Three species showed change but it was not statistically significant; chipping sparrow -76, oven bird +37, and white-throated sparrow +13.

The mean number of chicks in broods of wild spruce grouse in 1989 was 40% lower on the areas sprayed with *B.t.* (control N=17, $\bar{X}$=4.6, range 1-7; spray N=6, $\bar{X}$=2.8, range 1-4, $P<0.05$). Moreover, wild chicks in 1989 grew in grams 30% slower up to 14 days of age on the area sprayed with *B.t.* (control N=25, Y=2.19X + 11.69, $P<0.01$; spray N=19, Y=1.48X + 11.31, $P<0.001$, P slopes <0.05).

In 1990, captive chicks lived longer on the control areas than on the areas sprayed with *B.t.*$_{30}$ (control, number living 3 to 8 days was 16, and 9 to 14 days 5 or 24%; spray, for the same periods, 23 and 2 or 8%, $P<0.1>.05$). Moreover, chicks grew better on control areas than on areas sprayed with *B.t.*$_{30}$. Spray chicks never gained weight. Control chicks held hatch weight and at 5 days of age to 14 days made strong growth. Controls were significantly heavier at 5 days of age (control N=15, $\bar{X}$=14.8; spray N=21, $\bar{X}$=12.8, $P<0.05$).

We continue to count and analyze samples of insects obtained in

1989 and 1990. In the south forest in 1989, caterpillars on low plants declined as much as 65% after spraying with *B.t.*$_{30}$. Prespray abundance was similar on the spray and control blocks. Postspray (after June 11) caterpillars were significantly fewer in the spray block for 4 weeks ($P<.01$). Among at least 10 Orders of arthropods counted in the south forest only the Lepidoptera were decreased by the spray, ants and grasshoppers apparently increased, the others were unaffected.

Conclusions: *B.t.*$_{30}$ caused losses in 3 species of song birds and increased mortality and decreased growth in chicks of wild spruce grouse. Results from captive chicks support the conclusions from wild chicks.

B.t.$_{30}$ sprayed from the air into the forest canopy, knocked down caterpillars of low shrubs and herbs up to 65% over 4 weeks.

Birds needing caterpillars as food were: chicks of spruce grouse and breeding; yellow-rumped warbler, nashville warbler, and hermit thrush.

The impact of *B.t.* may be mitigated by adjusting the date of spray to reduce the kill of caterpillars of low shrubs-and herbs, and confining spray to the canopy.

Brandle, J.E. and Potter, J.

Sustainable alternatives to fumigation for the control of root lesion nematodes.

In 1988, 766,800 kg of synthetic chemical soil fumigants were applied to tobacco (Nicotiana tabacum L.) crops grown on 24,300 ha of coarse textured soils in Southwestern Ontario. One of the major purposes of their use was to reduce crop loss associated with attack by root lesion nematodes (Pratylenchus penetrans Cobb.). No alternative means of nematode control have been developed. It was the overall goal of this project to reduce dependence on chemical nematicides by developing non-chemical methods of control.

One key ingredient in some commercial soil fumigants is methyl isothiocyanate, a compound closely related to the isothiocyanates produced upon hydrolysis of glucosinolates present is the tissues of some Brassica species. When leaf tissue is crushed in the presence of water, an enzyme known as myrosinase reacts with the glucosinolates present in the tissue to produce a number of biologically active products. The nature of the hydrolytic products depends on which glucosinolates are present in the tissue and the conditions (e.g. pH) under which the reaction takes place. Some of these hydrolytic products are known to affect herbivorous insects and some fungi. In India, mixed cropping systems involving cereals and Brassica species have been found to result in control of a number of species of nematodes. Water extracts of mustard cake have also been found to reduce nematode infestation of wheat roots. These latter results indicate that there is good potential for nematode control using Brassica species and that the hydrolysit products of glucosinolate reaction with myrosinase are probably responsible for the nematicidal activity that has been observed. It was the purpose of the first stage of this project to evaluate a number of Brassica species for nematicidal activity and for their ability to act as hosts for the root lesion nematode.

Glucosinolate profiles of six Brassica species and cultivars were evaluated using gas chromatography. The various Brassica napus cultivars have similar aliphatic glucosinolate profiles, but Westar and Midas bad lower total concentrations of glucosinolates than Jet Neuf. Brassica juncea cv. Domo is the only species which contained significant amounts of allyl glucosinolate. Raphnus olieferus cv. Trick and Sinapis alba cv. Asta have profiles similar to those found amongst the B. napus cultivars. Gas chromatography does not give a reliable estimate of the concentrations of aromatic or indolyl glucosinolates; therefore, more detailed analysis using HPLC will be required to fully resolve all possible glucosinolates present in the tissue.

Results of screening for nematicidal activity indicates that leaf extracts from all species were able to immobilize nematodes after 24 hours exposure. There were differences among the leaf extracts in terms of their ability to immobilize nematodes during the first six hours of exposure. Leaf extracts from Domo were substantially

more effective during the first six hours of exposure than extracts from the other species. Westar and Midas leaf extracts were the least effective during the first six hours. Nematodes exposed for 24 hours to Westar leaf extracts showed the highest level of recovery after transfer to fresh water. The low concentration of glucosinolates in the leaf tissue of Westar and Midas is the most likely reason for the low toxicity of leaf extracts. Jet Neuf, Asta and Trick showed some recovery after transfer to fresh water indicating that the hydrolytic breakdown products resulting from reaction of glucosinolates with myrosinase from these species were not highly toxic to root lesion nematodes. There was no recovery from exposure to leaf extracts from Domo illustrating that the glucosinolates present in the leaf tissues produce highly nematicidal compound(s) upon hydrolysis.

Hydrolysis of the major glucosinolates present in the leaf tissues Jet Neuf, Midas, Asta and Trick results in the production of a thiocyanate ion and an indolyl alcohol. Neither the indolyl alcohol nor the thiocyanate ion would appear to be extremely toxic to root lesion nematodes. Observation of Trick leaf extracts does indicate that longer exposures (e.g. 5 days) may be necessary before complete toxicity is observed. The major glucosinolate present in leaf tissue of Domo is allyl glucosinolate, which forms at stable isothiocyanate (allyl isothiocyanate) upon hydrolysis. Nematodes exposed to pure allyl isothiocyanate were killed very quickly. Concentrations of allyl isothiocyanate above 1 μmol/mL were found to immobilize nematodes within 30 minutes, concentrations above 5.5 μmol/mL were effective within 10 minutes and above 8.5 μmol/mL within 5 minutes. Allyl glucosinolate alone did not have any effect on nematodes; however, a mixture of allyl glucosinolate and the enzyme myrosinase resulted in rapid nematode mortality indicating that the allyl isothiocyanate released upon hydrolysis of allyl glucosinolate was probably the nematicidal factor present in the Domo leaf tissue extract. Further detailed chemical analysis of the leaf tissue extracts will be required in order to confirm this hypothesis. A bioassay designed to evaluate the concentration of allyl isothiocyanate present in leaf tissue was developed.

Preliminary experiments designed to evaluate the ability of each of the different Brassica species and cultivars to act as hosts for the root lesion nematode are underway.

CUNNINGHAM, J.C. and W.J. KAUPP.

Field trials with two gypsy moth viral insecticides, Disparvirus and Gypchek, in 1990.

Following Disparvirus trials in 1988 and 1989, a double application of 5×10^{11} polyhedral inclusion bodies (PIB/ha) for a total of 10^{12} PIB/ha, in an aqueous tank mix, at an emitted volume of 5.0 L/ha, was recommended for gypsy moth control. Disparvirus is a nuclear polyhedrosis virus product from the Forest Pest Management Institute. The tank mix contained 25% v/v molasses, 10% w/v Orzan LS lignosulphonate and 2% v/v Rhoplex B60A sticker. It is cumbersome and unsuitable for commercial applicators. Two parameters were tested in 1990, 1) an emitted volume of 2.5 L/ha was compared to 5.0 L/ha using Disparvirus in the aqueous tank mix, 2) an emulsifiable oil tank mix was tested at 5.0 L/ha. There was insufficient Disparvirus for this test and Gypchek was obtained from USDA Forest Service colleagues. The oil was the blank carrier vehicle for the Bacillus thuringiensis product, Dipel 176, and was provided courtesy of Abbott Laboratories. A 25% oil, 75% water emulsion was applied. The same dosage of virus was used in all treatments, a double application of 5×10^{11} PIB/ha and 3 different treatments were each replicated on 3 plots (oak predominant species) of about 10 ha each in Simcoe District. The treatments were 1) Disparvirus in the aqueous tank mix at 2.5 L/ha 2) Disparvirus in the aqueous tank mix at 5.0 L/ha and 3) Gypchek in the emulsifiable oil tank mix at 5.0 L/ha.

A Cessna Ag truck fitted with 4 Micronair AU 4000 rotary atomizers was used for all applications. The first spray was applied to all plots on May 14 when 99.8% of larvae were in the first instar. The second application of the two Disparvirus treatments was 5 days later on May 19 with 85% first, 10% second and 5% third instar gypsy moth larvae. The second application of Gypchek was 8 days later on May 22 with 82% first, 16% second and 2% third instar larvae present. Leaves were about 50% expanded on red oak and 25% on white oak at the time of these applications. A further 4 plots were selected as untreated checks and paired with the 9 treated plots on the basis of pre-spray gypsy moth egg mass densities. Egg masses were counted in ten 0.01 ha sub-plots in each treated and check plot. In the assessment, pupal counts were made from burlap traps, post-spray egg mass surveys were made and population reductions due to the treatments calculated using a modified Abbott's formula. Defoliation estimates were made from 50 branch samples from each treated and check plot.

A treatment is considered satisfactory when the plot suffers less than 40% defoliation and when the post-spray egg mass density is below the threshold level of 1200/ha. Results from the 1990 trials are shown in Table 1. Results from the 2.5 L/ha Disparvirus treatment in the aqueous tank mix were considered unsatisfactory with one plot suffering 46% defoliation and two of the plots with egg mass densities above 1200/ha. Only one of the 3 replicates fulfilled the criteria for a successful application. Results from

the 5.0 L/ha Disparvirus application were better. The highest defoliation was 38% compared to 77 and 93% in corresponding check plots and only one plot had post-spray egg mass counts above 1200/ha. This was the plot with the highest pre-spray count of 8900/ha which was reduced to 1620/ha. The Gypchek in emulsifiable oil treatment gave excellent results. The heaviest defoliation was 35% in any of the treated plots and post-spray egg mass counts ranged from 556 to 880/ha. Population reductions due to treatment were 73, 82 and 90% for the Disparvirus at 2.5 L/ha, 87, 91 and 95% for Disparvirus at 5.0 L/ha and 87, 92 and 92% for Gypchek in oil at 5.0 L/ha. A reduction in volume from 5.0 L/ha to 2.5 L/ha cannot be recommended for the aqueous tank mix. However, results with the emulsifiable oil were most encouraging and it is recommended that this tank mix be tested at an emitted volume of 2.5 L/ha.

Table 1. Assessment of Disparvirus and Gypchek aerial spray trials.

Plot	Treatment[1]	Pupae/m burlap (±SE)	Pre-spray EM/ha2 (±SE)	Post-spray EM/ha (±SE)	% population change	defoliation of oak
Plot 1	1	12 ± 2	2280 ± 339	820 ± 164	-64	30
Check A	-	61 ± 6	2390 ± 471	8200 ± 1376	+243	46
Plot 2	1	14 ± 2	3620 ± 267	2230 ± 472	-38	46
Check C	-	43 ± 5	3430 ± 664	7710 ± 1147	+125	77
Plot 3	1	17 ± 2	3270 ± 588	1340 ± 305	-59	34
Check C	-	43 ± 5	3430 ± 664	7710 ± 1147	+125	77
Plot 4	2	8 ± 2	8900 ± 932	1620 ± 244	-82	38
Check D	-	37 ± 3	6690 ± 1152	9560 ± 1172	+43	93
Plot 5	2	11 ± 2	4360 ± 809	930 ± 130	-79	29
Check C	-	43 ± 5	3430 ± 664	7710 ± 1147	+125	77
Plot 6	2	2 ± 1	3870 ± 572	420 ± 81	-89	31
Check C	-	43 ± 5	3430 ± 664	7710 ± 1147	+125	77
Plot 7	3	9 ± 2	7560 ± 1574	880 ± 238	-88	29
Check D	-	37 ± 3	6690 ± 1152	9560 ± 1172	+43	93
Plot 8	3	8 ± 1	6780 ± 719	750 ± 168	-89	35
Check D	-	37 ± 3	6690 ± 1152	9560 ± 1172	+43	93
Plot 9	3	3 ± 1	3080 ± 376	556 ± 279	-82	30
Check B	-	15 ± 1	2920 ± 552	4810 ± 1181	+65	77

[1] Treatment 1 = Disparvirus in aqueous tank mix at 2.5 L/ha
Treatment 2 = Disparvirus in aqueous tank mix at 5.0 L/ha
Treatment 3 = Gypchek in emulsifiable oil tank mix at 5.0 L/ha

2 Egg Masses/hectare

DAY, D.

The ecotoxicological impact of agricultural runoff in streams: The effects of atrazine, metolachlor and nutrient interactions on primary productivity of attached algae.

Scope and intent of research:

A major community in all aquatic ecosystems is the Aufwuchs or periphyton which consists of a diverse group of algae and other microbiological organisms found attached and growing underwater on natural substrates. As primary producers, the periphyton provide both a habitat and a major energy source for many larger aquatic organisms and thus play a very important role in the structure and function of aquatic ecosystems. In rivers and streams, the periphyton are probably one of the first groups of biota to be exposed to contaminants in surface runoff and/or accidental overspray, and by virtue of their immobility, these communities cannot escape the impact of toxic chemicals in their ambient environment.

Atrazine and metolachlor have been found in surface waters in North America which drain areas of land undergoing intensive agriculture, especially corn production. Residues are highest during spring runoff, around times of application and during storm runoff events. Numerous algal species have been shown to be sensitive to herbicides which are common in agricultural areas but few studies have investigated the impact of such chemicals on attached algal communities. In addition, few methodologies are available to determine the short- and long-term effects of herbicides on periphyton in riverine environments.

Therefore, the first **objective** of this research is to develop the methodology to determine the effects of several herbicides (i.e., atrazine and metolachlor) on attached algae found growing in aquatic lotic ecosystems next to agricultural land. Data are also needed on the synergistic, antagonistic and/or additive effects of pesticides in combination with other agricultural contaminants such as phosphorus and nitrogen. Therefore, a second **objective** is to determine the effects of these herbicides in combination with other chemicals found in agricultural runoff.

Progress of Research:

1. During the late spring, summer and early fall of 1990, in situ measurements of the effects of short-term doses of atrazine (nominal 25, 50, 100 and 200 μg/L) and metolachlor (nominal 50, 100 and 500 μg/L) on the primary productivity of attached algae on natural rock substrates were performed with a specially constructed portable streambank incubator (modified from an original design developed at the University of Guelph). Rocks were incubated in individual 1.5 L cylindrical plexiglass chambers placed in a clear plexiglass tank. The water in the chambers was kept in circulation

by magnetic stir bars fitted with vertical baffles spun by rotating magnets chain-driven by a gas generator. Stream water was circulated through the plexiglass tank with a 12V bilge pump to maintain chambers close to stream temperature. Primary production was measured using the light-dark method while monitoring oxygen concentrations using a YSI digital dissolved O_2 metre. For each concentration of pesticide tested, triplicate light and dark (painted with brown opaque paint) chambers were dosed with pesticide and monitored for up to 4 hours. Six light and dark plexiglass chambers remained untreated as controls. Pesticide concentrations were determined analytically by GLC. Following each experiment, all rocks were taken to the laboratory and their organic layers were quantitatively sampled for dry and ash-free weights and chlorophyll a concentrations. Net primary production and respiration in the presence and absence of pesticides was determined and expressed as mg O_2/mg chl a/h. As in 1989, results indicate that concentrations of atrazine ≤100 µg/L result in a reduction in net primary productivity following short-term exposure. Metolachlor had no effect on primary production at any of the concentrations tested.

2. The use of the portable bankside incubator allowed the determination of the short-term effects of a "pulsed-dose" of pesticide such as would occur during a storm runoff event. However, in order to determine the longer-term effects of low, ambient levels of pesticides on the growth of periphyton and to determine the interactive effects of differing nutrient levels in combination with herbicides, another bioassay system was employed in the laboratory. Twelve recirculating stream bioassay units (each holding approximately 35 L of water) were utilized in the laboratory under controlled temperature and light regimes. Each tank contained a base designed to hold vertical acrylic rods which serve as artificial substrates for the attachment of stream algae. Algal growth on the acrylic rods was provided by seeding each tank using a homogenate of periphytic growth scraped from rocks obtained in local streams. Experiments were designed to allow the growth of periphyton for a period of three weeks under low (5 µg/L phosphorus and 400 µg/L nitrogen), medium (100 µg/L phosphorus and 500 µg/L nitrogen) and high (1000 µg/L phosphorus and 1500 µg/L nitrogen). Tanks were then dosed with 25, 50 or 100 µg atrazine/L. Replicate acrylic rods were sampled on a regular basis throughout the experiments for attached algae and data are expressed in terms of ash-free dry weight/cm^2 and chlorophyll a/cm^2. Results indicate that levels of ≤100 µg atrazine/L had no significant effects on the growth of periphyton under differing levels of nutrients.

In conclusion, the results of this study suggest that ambient levels of atrazine and metolachlor found in agricultural streams (≤100 µg/L and ≤25 µg/L, respectively) have no long-lasting detrimental effects on the growth of attached algae; however, higher concentrations which may occur (at least with atrazine) may temporarily reduce photosynthesis.

Deschamps, Raymond J.A. and Hall, J. Christopher

An Overview of Immunochemical Techniques for Pesticide Detection in the Environment

Immunoassay provides the analytical chemist with another tool for detecting and quantitating pesticides in environmental samples. Immunoassay relies on the highly specific binding of an antibody to its antigen. This technology is intended to complement rather than replace existing methods of detection such as gas liquid chromatography (GC) or high performance liquid chromatography (HPLC). Over the past four years, we have developed immunoassays for several pesticides including 2,4-D, picloram, atrazine, metolachlor, metalaxyl, and an experimental graminicide XRD. Several immunoassay formats including radioimmunoassay (RIA), indirect enzyme immunoassay (iEIA), and direct enzyme immunoassay (dEIA) have been employed, although we have most commonly used an immobilized antigen indirect enzyme immunoassay. In most cases, we have achieved very sensitive assays based on polyclonal antisera obtained from New Zealand White rabbits. With these assays, pesticide concentrations in the low ppb range can be determined. However, in two cases where both polyclonal and monoclonal antibodies were available for comparison (picloram and atrazine), the monoclonal antibody-based assays were found to be superior in terms of sensitivity. These assays have been applied to the analysis of environmental samples such as water, soil, and plant material with a great deal of success. However, certain matrix interferences must be accounted for such as pH, ionic strength, and organic matter content. This is most easily accomplished by employing a reference matrix in the assay that is similar in composition to the sample matrix. Alternatively, matrix interferences may be removed by dilution or by solid phase extraction on disposable cartridges. We have found that water as a sample matrix is very compatible with immunoassay. Soils and plant material are more problematic due to the organic matter content of the sample extracts. Specific examples from the research will be highlighted to illustrate the potential advantages and limitations of immunoassay as a method of detection.

Hofstra, G. and Knight, R.

The Effect of Soil Nitrate on Weed Populations

The objective of this research was to determine if the level of nitrate in the soil environment affects the structure of the weed population. One of the factors affecting the weed population has been identified as the breaking of seed dormancy and subsequent germination and emergence of seedlings. The laboratory experiments were designed to determine if nitrate levels found in the soil increased germination of certain species. The field experiments were designed to determine if nitrate affected the emergence of different ores and the resulting structure of the weed community.

Field plots. The experiment was performed as a RCBD split plot design, with the level of nitrate applied as the whole plot factor and the method of application as the subplot factor. Plots were 1 meter square (.5 x 2 m) and subplots were 0.5 meter square (.5 x 1 m). Plots were separated by a .5 m strip and blocks were separated by a 1 m strip. Before beginning any treatments a nitrate analysis was performed using 10 soil samples randomly collected from the site. The average nitrate level (15 kg N/ha) was used as control and base level to calculate treatments. Plots were rototilled and raked on May 11. On May 23 the plots were raked a second time and all seedlings were removed.

On May 24 calcium nitrate fertilizer was applied to subplots at rates calculated to raise soil nitrate to 5 different levels 200, 150, 100, 50, and 25 kg N/ha. The base level of 15 kg N/ha was treated with water only as the control. The calcium nitrate (14.5% granular nitrate) was dissolved in 2 litres of water and watered into the subplots. In one half of the whole plot the desired rate of nitrate was applied at 100% of the treatment rate at the beginning of the experiment. In the other half of the plot the nitrate was split applied with 50% of the treatment applied at the beginning and 50% applied one month later.

Seedlings were harvested and identified from each subplot at three different times June 12, July 10 and July 31, 1990. A .25 x .25 m permanent quadrant from the centre of the subplot was used for each harvest. Soil samples were taken at the same time. Five soil cores of 15 cm depth were taken from outside of the quadrant. Soil nitrate was determined by KCl extraction from a pooled sample of 5 cores for each subplot. Plots were raked after the first seedling harvest on June 12 but not thereafter due to obvious effects of disturbance and to simulate cropping conditions.

A positive linear relationship was found between the cumulative number of seedlings harvested and the level of nitrate applied. There was no significant difference found between the timing of nitrate application. The dominant species found were lambquarters, pigweed, shepherd's purse (Capsella bursapastoris (L.) Med., thale cress (Arabidopsis thaliana (L.) Heynh), and witchgrass (Panicum capillare L.). An analysis on the relationship of nitrate

concentration and the community structure is ongoing.

In comparing observed nitrate levels in soil samples to nitrate levels applied, the observed nitrate levels did not correspond to expected values and variability was found between repetitions. From this information it is difficult to predict the exact concentration of nitrate that the seed is subjected to in the field environment.

Seed Germination. Germination of 6 different weed species was compared under various nitrate concentrations. The weed species included Chenopodium album L. (lambquarters), Amaranthus retroflexus L. (redroot pigweed), Abutilon theophrasti Medic. (velvetleaf), Setaria viridis (L.) Beauv. (green foxtail), Setaria glauca (L.) Beauv. (yellow foxtail) and Digitaria ischaemum (Schreb.) Muhl. (smooth crabgrass). The seeds were obtained from different sources and sources were compared.

Seeds were placed on a double layer of filter paper in 14 cm petri dishes. Nitrate solutions ranging from 2000 ppm to 0 ppm ($Ca(NO_3)_2$) were applied at 20 ml per dish. Three replicates per treatment were applied to 100 seeds. Seeds were incubated in a germination cabinet at a controlled regime of 16 hours darkness at 5°C and 8 hours of light at 25°C. The humidity was approximately 100% RH. Germinated seeds were counted and removed every 3 days for a period of 3 weeks or until no further germination occurred.

A positive linear relationship was found between nitrate concentration and germination in the lambquarters seed only. This relationship varied among seed sources. In the grass species it was difficult to obtain seed sources which had at least partial dormancy.

From these experiments it can be concluded that nitrate affects weed seed germination, but it is difficult to determine if nitrate is involved in breaking dormancy or whether nitrate is a factor required for germination for some seeds.

Hofstra, G., Stasiak, M. and Fletcher, R.A.

Effects of reduced rates of glyphosate on control of broad-leaved trees in conifer plantations.

This research was undertaken to establish justification for a decrease in the application rate for glyphosate in conifer release, and to establish what parameters could be used as sensitive indicators of potential glyphosate injury. This was effected by determining the survival and growth rate of broad-leaved species in mixed-wood stands after treatment with low levels of glyphosate, and determining low level effects of glyphosate on various physiological processes.

Field Plots. Glyphosate at rates of 100, 25, 10, 5, 2, and 0 percent of the recommended field rate of 2.1 kg/ha (RFR) was applied to separate plots of pin cherry (Prunus pensylvanica L.) and trembling aspen (Populus tremuloides Michx.) in the Thessalon area of Northern Ontario. Plots were assessed at the end of the growing season one and two years following application, and data from both years was combined for statistical analysis. Parameters recorded included percent mortality, visual injury, leaf and stem length, and shikimic acid levels.

Glyphosate applied at 100% RFR caused complete necrosis of the trees and herbaceous understorey within four weeks of application in plots of both pin cherry and trembling aspen. The 25% application also produced injurious effects on both species in the form of necrotic spots and a deeper red colouration on the leaves. The glyphosate applications at lower rates elicited some chlorosis of the younger leaves within four weeks of application. Mortality and visual injury was generally greater in the second year than in the first. The 25% RFR applications resulted in percent mortalities of 42 and 46 after one year and 40 and 55 after two years in pin cherry and trembling aspen respectively. Mortality response was linear with respect to application rate. The lowest rate at which statistically significant visual injury was observable in pin cherry plots was 10%, and 2% in trembling aspen.

Although mortality and visual injury were observable at rates as low as 2% RFR, morphological changes were generally not statistically significant until at least 10% was applied. At this rate, pin cherry showed a 45% reduction in stem length and a 23% reduction in leaf length one year after application. Two years after glyphosate application to pin cherry, the 2% application showed a 34% reduction in stem length, but no significant change in leaf length. Trembling aspen one year after application showed a similar reduction in stem length (34%) as pin cherry at 10%, but no significant reduction in leaf length was seen (21%) until 25% was applied. Two years after the initial application to trembling aspen, a significant reduction in stem length was seen at 2%, and in leaf length at 10%.

One day after glyphosate application, large increases in shikimic

acid concentrations in leaf tissue were observed at 10% RFR in pin cherry and at 100% in trembling aspen. The lowest application rate for which there were significant increases in shikimic acid was 10% in both species. No increases in shikimic acid levels were observed one or two years later in surviving trees at any of the glyphosate application rates examined, even though symptoms of glyphosate injury continued to be exhibited. The increases in acid, even at lower application rates, could be a useful tool for assessing glyphosate damage to non-target trees soon after exposure because increases in shikimic acid are detectable prior to any visible symptoms of injury.

Controlled conditions: White birch (Betula papyrifera Marsh.) seedlings grown under controlled environmental conditions were treated with glyphosate at rates of 0, 1, 2, 5, and 10% RFR. Leaf fluorescence, chlorophyll and carotenoid content, total sugars, ethylene and changes in various shikimic acid pathway products were measured. As well, birch and trembling aspen seedlings, grown outdoors, and treated with glyphosate were evaluated for changes in acid for comparative purposes between field and growth room studies.

The chlorophyll and carotenoid content did not change in the older sprayed leaves until necrosis became apparent, however, young expanding leaves showed significant decreases in chlorophyll a, with less apparent decreases in chlorophyll b and carotenoids, within three days of treatment. Within three days of application, glyphosate treated birch seedlings showed a significant increase in total sugars with respect to control plants. Changes in chlorophyll fluorescence, an indication of photosynthetic efficiency, were observed at the highest level of application (10% RFR) after 24 hours, and by day 7, all treatments had deviated significantly from the control. Ethylene evolution induced by glyphosate applied to birch seedlings increased with concentration and increases and are seen as early as 1 day after treatment at higher levels of glyphosate.

Glyphosate blocks 5-enolpyruvyl shikimic acid-3-phosphate (EPSP) synthase in the shikimic acid pathway. This blockage was shown to elicit increases in gallic, and p-hydroxybenzoic acids (Figure 1), which are phenolic compounds formed in this pathway before the EPSP synthase blockage. Phenolic acids are often implicated in allelochemic defense mechanisms of plants insect and disease attack. Alterations in phenolic content could alter these mechanisms, and consequently, low level glyphosate applications could increase susceptibility of trees to attack from other organisms. This may in part explain the increased mortality observed in field plots of both species 2 years after treatment with glyphosate.

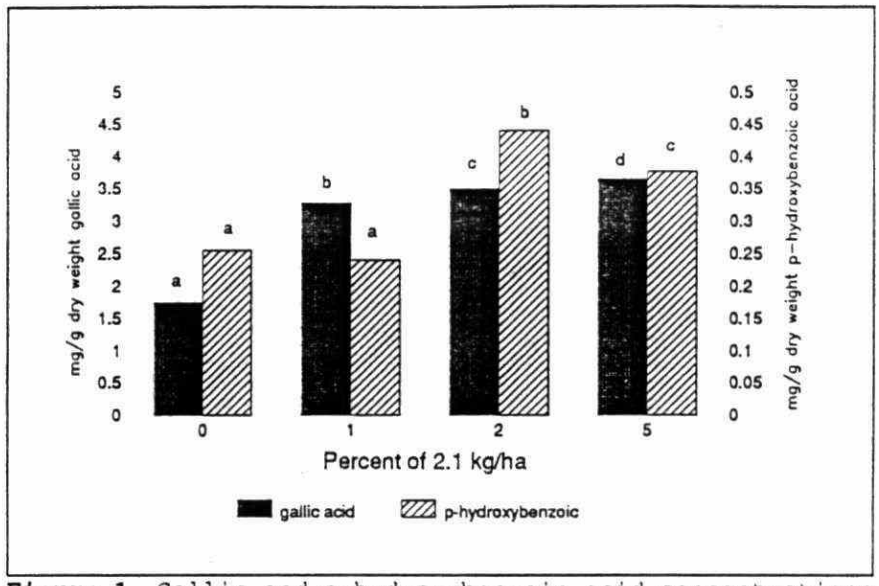

Figure 1 Gallic and p-hydroxybenzoic acid concentrations in birch leaf tissue after treatment with 0, 1, 2, and 5 percent of 2.1 kg/ha. Bars with the same letter were not significantly different (p = 0.05)

Recommended rates for the control of unwanted vegetation in conifer plantations range from 1 to 2 kg/ha (WSSA 1983) and are in fact recommended at rates of 3 to 6 kg/ha by the manufacturer. In general, these rates were developed to ensure complete kill of most species present. This study suggests that lower application rates could be sufficient to reduce competitive pressures by reducing growth and viability of unwanted vegetation and allowing conifers to become dominant. Reduction of glyphosate rates would also reduce the risk of conifer mortality in sensitive species, and minimize the environmental impact from silvicultural herbicide applications.

JAQUES, R.P. and LAING, J. E.

Effectiveness of the Granulosis Virus in Management of the Codling Moth in Apple Orchards and its Environmental Impact.

The codling moth, *Cydia pomonella*, is the most important insect pest of apples in Ontario. The insect damages the apple by burrowing through the pulp as the larva develops. Secondly, the insect is a problem because the chemical insecticides applied to control it are usually very disruptive to populations of parasitic and predaceous arthropods that regulate other pests. The minimum effect on nontarget arthropods indicated by preliminary studies is a major reason for our interest in development of the granulosis virus as an alternative to chemical insecticides for control of the codling moth. In addition, use of the virus to protect apples and pears against the codling moth would greatly enhance the competitiveness of nonchemical production of apples in Ontario.

Research in 1990 included plot tests in apple and pear orchards on the effectiveness of the virus against the codling moth, laboratory bioassays to determine the persistence of activity on the fruit and foliage, and orchard studies on the effect of applications of the virus on nontarget predaceous and parasitic arthropods. The studies on nontarget arthropods were carried out at the University of Guelph and will be reported separately.

Granulosis virus was applied 6 times at a rate of 1.5×10^{14} granular inclusion bodies/ha/application to a 120-tree plot in the portion of Farmer Jack's Orchards in Lambeth that was managed according to an organic program. The first application (June 5) was applied when 100 degree-days (base 5°C) had accumulated after the first capture of codling moth in pheromone traps; subsequent applications were on June 13, 21, July 5, 13, and 25. Aqueous spray mixtures containing a spreader-sticker (Niagara Super-Spred) 0.05% v/v, skimmilk powder 0.5% w/v, and virus were applied using a compressed air hand sprayer (480 kPa pressure) (45L/120-tree plot). At harvest, apples were examined to enumerate shallow and deep entries by codling moth larvae. Apples were picked from trees in the virus-treated plot, from trees treated by the organic management system without virus, and from trees treated by an integrated pest management program in which Imidan 50 WP was applied for control of the codling moth. In addition, drop apples were examined for damage. Fruit and foliage on virus-treated trees and trees in the organic block and soil under the trees were sampled at intervals for subsequent determination of residues of active virus by bioassay procedures.

The data (Table 1) indicated that application of the virus substantially reduced deep entries by codling moth larvae compared to the frequency of damage in trees managed by the organic system but not treated with the virus. Damage to the virus-treated apples was greater than to apples treated by the IPM program. Shallow entries, which may result from aborted entry into the apple after a minimum of feeding, were more common in virus-treated apples than

in apples from other plots. Larvae usually die within 2 days after ingestion of the virus; this incubation period may allow limited feeding before death. Shallow-entry damage may downgrade the apple but does not render it unmarketable.

These efficacy data demonstrated that the virus is an effective alternative to chemical insecticides to control the codling moth. Use of the virus would be particularly attractive in management of orchards when minimum use of chemicals is desired.

In other studies on efficacy, apple and pear trees in small plots at Harrow were sprayed with CpGV. Populations of the codling moth adults were sparse and damage to apples was too infrequent to provide definitive data.

Persistence of activity of the virus on foliage and on the apple after application is a significant factor in effectiveness in control of the codling moth because of the feeding habits of the insect and because of the long period over which eggs hatch. Small larvae feed for a very short period on exposed surfaces before entering the apple and, therefore, it must eat a lethal dose of the virus in a very short feeding period. Earlier studies on this and other viruses of this type have indicated that deposits of virus are 50% inactivated by exposure to sunlight for 2 days. Data from bioassays on samples of foliage and apples from our 1990 plots were not definitive because of the high mortality of nontreated check larvae.

Granulosis viruses and polyhedrosis virus are known to persist for long periods in soil. Data on persistence of the codling moth granulosis virus is of particular interest in regard to environmental safety. Although, the data from bioassays in 1990 were not reliable because of the high mortality of nontreated check larvae in the tests, there was no evidence of occurrence of the virus in soil of treated orchards.

It is planned to continue these studies in 1991. The test at Lambeth will include a comparison of the effectiveness of the virus with pheromone releases to disrupt mating of the codling moth and will include a combination of these nonchemical methods for control of this past. Efficacy of the virus and persistence in soil and on foliage will be included in the 1990 study. It is planned to continue the study on environmental impact at the University of Guelph and to a lesser extent in the trial at Lambeth.

Funding for student assistance for studies in 1990 by a grant by the Ontario Pesticide Advisory Committee is gratefully acknowledged.

Table 1. The Effectiveness of the Granulosis Virus of the Codling Moth on Apples, Lambeth, Ontario. 1990.

		% Apples with Codling Moth Entries		
		Picked		Drop
		Shallow	Deep	Deep
CpGV[1]	McIntosh	13.8	3.5	6.2
	Ida Red	8.6	5.4	--
Organic	McIntosh	6.3	14.0	34.7
	Ida Red	3.0	24.0	--
IPM	McIntosh	0	0	0
	Ida Red	0.3	1.0	--

[1] Codling moth granulosis virus

Jarvis, W.R., and Kochan, Jane

The compatibility of a biological control for powdery mildew with chemical pesticides.

In order to make the maximum use of biological pesticides, they have to be compatible with conventional chemical pesticides that might be used in integrated plant protection programs, and conversely, they must not adversely affect other biological control organisms in the programs.

The goal of this project was to examine the interactions of two fungi in the genus Stephanoascus which we being used for the biological control of powdery mildew (Sphaerotheca fuliginea) on greenhouse cucumber.

A number of insecticides and fungicides which we registered for use on greenhouse cucumber and recommended in Ontario were assayed for activity against the Stephanoascus spp. in three main ways; the standard poison-agar technique; comparison of fungicidal and fungistatic activity; and in vivo activity of the pesticides in the greenhouse environment.

In all, 10 fungicides and 11 insecticides were assayed (herbicides are not used in greenhouse cucumbers). For poison-agar and fungistatic assays, concentrations of active ingredients started at the Ontario-recommended commercial rate and some of the materials were also serially diluted in 10-fold steps.

Simultaneous fungistatic and fungicidal activities were assayed by the technique of Neely & Himelick (Phytopathology 56: 203-209, 1966), a 2-h exposure being given to assay fungicidal activity. For this, spores were put into contact with higher concentrations of the pesticide suspension on a cellophane film which was removed to a non-pesticide agar medium after the exposure period. Fungistasis was judged to have occurred if 99% or more of the spores failed to germinate on low pesticide concentrations within 24 h.

In vivo, Stephanoascus sp. was applied as a conidial suspension spray to cucumber leaves, cv. Corona, followed the next day by a pesticide at the standard commercial rate. After 1 and 7 days, leaf discs were removed and the viability of the Stephanoascus inoculum was determined on malt-yeast agar.

All of the fungicides except microfine sulfur significantly retarded the growth of Stephanoascus in poison-agar. Benomyl, Kocide, mancozeb, dodemorph and maneb inhibited growth of S. flocculosus completely. In addition, ferbam and iprodione severely retarded the growth of S. flocculosus, and completely inhibited the growth of S. rugulosus. S. rugulosus was also inhibited by benomyl, Kocide, mancozeb, dodemorph captan, and

maneb. In general, insecticides were less toxic; dipel severely retarded the growth of S. flocculosus, but not of S. rugulosus. Dicofol and Safer's soap reduced the growth of both fungi to less then 50% of the chock growth rate.

With the exception of captan and maneb, no pesticide inhibited the germination of spores of S. flocculosus after a 2-h exposure, but continual exposure to the pesticides gave substantially similar results as the poison-agar tests.

As is not uncommon with pesticide assays, in vitro results did not always fit well with in vivo results. On cucumber leaves, benomyl and dodemorph had relatively little effect on the viability of spores of S. flocculosus recovered after a 1-day exposure to the pesticides. Of the fungicides, maneb, mancozeb, and captan inhibited growth the most, and while dienochlor and permethrin permitted growth of over 80% of to check rate, fenbutatin oxide, and Safer's Insecticidal Soap reduced growth to less than 20% of the check rate.

Time did not permit the assay of the activity of Stephanoascus spp. on the insect biocontrols Encarsia formosa, Phytoseiulus persimilis, and Amblyseius cucumeris but no adverse effects were noted on the biocontrol of greenhouse whitefly Trialeurodes vaporariorum and Western flower thrips Frankliniella occidentalis.

These results enable the integration of a biological powdery mildew fungicide into greenhouse crop protection to be planned with greater confidence.

Hodge, V.A. and Kaushik, N.K.

Impact of Algal Fibrils on the Bioavailability of Pesticides to Non-Target Aquatic Organisms.

Dissolved organic matter (DOM) comprises many different components, one of which is a colloid rich fraction which primarily consists of fibrils of algal origin. These fibrils have the capacity to bind and hold cations in water. Their structure is rich in uronic acid residues and carboxyl groups which gives them this binding capability. Therefore, the objective of this study was to investigate the interactions between DOM (as fibrils) and selected contaminants in water.

Fenvalerate (a pyrethroid insecticide), pentachlorophenol (PCP) and copper (as copper sulphate) were selected to represent a range of different types of compounds to investigate this interaction. Stock solutions of fenvalerate (EC formulation) and PCP (technical) were prepared in acetone and a 1000 ppm solution of copper was made in distilled deionized water. Solutions were protected from the light and held at 4°C in order to minimize degradation.

Two different fibril sources were used in this study, pectin from apple and polygalacturonic acid from orange (pga) (Sigma Chemical Co., St. Louis, MO, USA). An earlier part of this study used a sample of lake fibrils obtained from Lake St. George, Ontario. However, the amount of time and expense involved with isolating such samples prohibited further experiments. Algal fibrils are similar in structure to pectin which justified the use of these commercial products as suitable substitutes. Fibrils were included at concentrations of 4, 8, or 50 mg/L with a range of concentrations of either fenvalerate, PCP or copper sulphate.

Standard 48 hour bioassays were employed, using Daphnia magna, $\leq$ 24 hours old as the test organism, in 100 ml beakers. Each beaker contained 5 to 10 organisms with a minimum of 25 organisms per treatment. The endpoint used for die tests was immobility measured as the inability of a daphnid to swim during a 10-second interval following gentle prodding with a glass probe or swirling of the water in the beaker. Probit analysis was used to generate EC50 values from test results and ANOVA was used to compare treatments. Mean EC50 values were determined with a program for analyzing synergistic ratios.

Mean EC50 values were generated from each set of treatments. Results indicated that there were no significant differences between the treatments of fenvalerate plus pectin (4, 8, and 50 mg/L) and fenvalerate alone ($p > 0.05$). Daphnids were exposed to these same treatments again, but after the test solutions had been left sitting for a 24-hour period. This "mixing" period was included in order to ensure there had been adequate contact time if this was to be a factor in reducing bioavailability. Although there were no significant differences between these treatments and

fenvalerate alone, overall the toxicity of fenvalerate was reduced in treatments where solutions were left for a period of 24 hours.

Treatments of fenvalerate plus polygalacturonic acid also showed that a 24-hour "mixing" period appeared to reduce the toxicity of fenvalerate overall. However, another trend was evident which indicated that the toxicity of fenvalerate in treatments with 50 mg/L polygalacturonic acid, with and without a 24 hour mixing period (2.05 and 1.49 µg/L respectively), was reduced from that of fenvalerate alone (1.43 and 1.06 µg/L respectively).

The toxicity of copper sulphate was not significantly reduced in the presence of 50 mg/L of pectin or polygalacturonic acid.

Results (mean EC50) for PCP showed a trend of increased toxicity of PCP between treatments of PCP alone, 24 and 48 hour test intervals (1.20 and 1.01 mg/L respectively) and treatments of PCP plus pga at both test intervals (both at 0.76 mg/L).

It appears that polygalacturonic acid may affect the bioavailability of certain contaminants but that this effect may differ as was indicated with these results.

A significant adhesion reaction was found to occur between the fibrils and Daphnia magna in treatments where fenvalerate was present. The fibrils adhere to the swimming antennae and spine of the daphnids which then interferes with normal swimming activity. Daphnids then stick to the beaker, or get tangled up in clumps with other daphnids and shed carapaces. In tests where immobility is used as a criteria for assessment, this could confound and influence test results. It is important to be aware of this side effect when conducting studies which incorporate fibrils, or other forms of DOM, with contaminants.

A second objective of this study was to manipulate an alga in the laboratory to produce fibrils. This would provide a source of fibrils for further study as well as indicate the cause or trigger for fibril production and at what levels. The chosen alga, Anabaena cylindrica, was grown in 300 ml flasks at 18°C (± 2), 16:8 hours light:dark and constant agitation. Growth was monitored daily with cell counts and absorbence measurements (441 nm) using a spectrophotometer. Two approaches for triggering fibril production were considered: varying phosphorus levels in the algal medium and sudden introduction of a contaminant, atrazine. Cultures were 7-10 days old at the time of exposure and in log phase of growth. Two crude methods, ruthenium red adsorption and a carbazole uronic acid reaction, were used in order to measure changes in fibril production in cultures before and after the treatments. Cultures exposed to atrazine (at approximately 10 mg/L) did not appear to show any significant differences in fibril production after 12 hours. It has been noted that, in general, fibril production increases as the culture ages.

These colloidal structures may be an important component when

considering the impact of pollutants on an aquatic system. By discovering more about their existence, valuable information may be gained which could be useful in studying contaminant interactions. A natural and abundant source of algal fibrils would be desirable in order to justify further study.

TOLMAN, J.H., McLEOD, D.G.R. and WHISTLECRAFT, J.W.

Evaluation of alternative methods of pest control for the home garden.

In 1986 Canadian home gardeners spent nearly $18 million on "garden chemicals", including insecticides. Reduction of this very significant insecticide use has been the overall objective of a multi-year study of alternative methods of pest control in the home garden. The potential of companion planting, oviposition deterrents, mass trapping and floating row covers was studied in 1990.

Based on previously collected monitoring results, a total of 28 home gardens in the city of London were divided into 4 groups of 7 with roughly equal populations of cabbage maggot (CM), onion maggot (OM) and crucifer flea beetles (FB):

A: CONTROL - no protection of radish, sett onion or cabbage
B: COMPANION PLANTING - radish, sett onion/marigolds
- cabbage/flowering leeks
C: COMPANION PLANTING - cabbage/dill
OVIPOSITION DETERRENT - radish sett onion/cayenne pepper
D: MASS TRAP - radish, sett onion, cabbage/large yellow pan trap baited with the attractant, allyl isothiocyanate (ASCN)

Damage to mature radish and sett onion was measured in 2 plantings, the 1st from May-June, the 2nd from July-mid August. Cabbage was transplanted in late May and harvested and graded in late August-early September. Neither marigold companion plants, nor cayenne pepper sprinkled in the seed furrow nor mass trapping of insects attracted to ASCN had a significant effect on CM damage to radish for either planting (Table 1).

TABLE 1: Cabbage Maggot Damage to Radish in Home Gardens - 1990 -

Treatment	Mean % Radish Damage	
	Planting 1	Planting 2
CONTROL	23.8 a*	5.4 a
Marigold Planting	17.6 a	11.8 a
Cayenne Pepper	17.5 a	9.2 a
Mass Trap	25.7 a	6.4 a

* - means within a column followed by the same letter are not significantly different (P = 0.05) as determined by Duncan's New Multiple Range Test.

Although OM damage to sett onion was lowest for both plantings in the presence of marigold companion plants, the reduction was significant only in the 2nd planting, perhaps due to larger

marigold plants later in the season (Table 2). Cayenne pepper sprinkled in the seed furrow and the operation of a mass trap had no significant effect on OM damage (Table 2).

TABLE 2: Onion Maggot Damage to Sett Onions in Home Gardens - 1990 -

Treatment	Mean % Onion Damage	
	Planting 1	Planting 2
CONTROL	15.4 a	15.6 a
Marigold Planting	6.3 a	5.9 b
Cayenne Pepper	12.3 a	18.1 a
Mass Trap	9.1 a	15.4 a

No alternative insect control practice (feeding deterrence in presence of dill companion plants, predation of larvae by vespids attracted to flowering leeks, mass trapping of insects attracted to ASCN), under the conditions of our experiments, had a significant effect on feeding on cabbage foliage by larval Lepidoptera (Table 3). There were no significant differences among treatments for either average individual head weight of harvested cabbage or the % of initial cabbage weight trimmed to obtain a marketable head (Table 3).

TABLE 3: "Insect" Damage to Cabbage in Home Gardens - 1990 -

Treatment	Mean % Cabbage Trimmed	Mean Head Wt. (kg)
CONTROL	15.15 a	1.62 a
Dill Planting	14.20 a	1.40 a
Leek Planting	16.10 a	1.68 a
Mass Trap	17.91 a	1.61 a

Replicated trials at the London Research Centre Field Station showed no differences among the 3 floating row covers in mean weights of harvested roots of radish or sett onion (Table 4). Radish grown under row covers were protected from feeding FB which virtually destroyed radishes in uncovered plots. All row covers significantly decreased individual bulb weight of sett onion (Table 4), perhaps due to reduced light intensity under the floating cover. Although no floating row cover had a significant effect on either number or weight of harvested sweet peppers (Table 4), all plots were infested by high populations of garden slugs; many fruits were damaged and results are therefore suspect.

TABLE 4: Effect of Floating Row Covers on Vegetable Productivity - 1990 -

Treatment	Mean Root Wt (g) Radish	Wt (g) Onion	Mean # Peppers/Plot	Mkt. Wt (g/Pepper)
Uncovered	2.75 a	25.64 a	14.3 a	193.1 a
Remay Cover	7.84 b	14.42 b	14.3 a	182.9 a
Kimberly Cover	7.03 b	16.98 b	7.8 a	180.9 a
Agronet Cover	6.00 b	17.54 b	16.0 a	191.9 a
diazinon G	3.96 a	26.85 a	---	---

Due to the press of other farm operations, the market gardener was unable to evaluate supplied Agronet floating row covers in his sweet pepper field.

Nealis, V.G.

Hyperparasitism and strategies for the biological control of gypsy moth in Ontario

The gypsy moth, Lymantria dispar, is an introduced pest to North America and threatens forest and recreational industries as well as amenity trees on residential land. There is a high demand for biological control alternatives because of the proximity of infestations to residential land where clients are sensitive to the need for environmentally benign pest control programs.

Pest control initiatives in the US employ a variety of control tactics either alone or in integrated control programs. This approach has encouraged the commercial production of insect parasitoids which can be mass-reared and released in large numbers as part of an inundative release program. Several species of parasitoids are now available and could be released in Ontario if their potential impact was considered sufficiently beneficial. A possible limitation to their impact, however, arises from native hyperparasitoids which have been found to be very common on other, established parasitoids of the gypsy moth.

The objectives of this study were to examine the impact of hyperparasitism on natural control agents of the gypsy moth in Ontario and to examine the relative vulnerability of new biological control candidates to this hyperparasitism. An established gypsy moth parasite, Cotesia melanoscela, is similar to several of the inundative release candidates and so was used as the principal monitoring tool and as the standard of comparison for vulnerability to hyperparasitism. Information gained from the study will lead to recommendations concerning the feasibility of particular biological control strategies for the gypsy moth.

The study of the impact of hyperparasitoids focussed on the species of hyperparasitoids attacking S. melanoscela in Ontario, their relative abundance and the seasonal pattern of attack. Data collection utilized both field collections of natural cocoons and the use of sentinel cocoons produced by rearing S. melanoscela in the lab and deploying these cocoons for one week intervals throughout the field season.

As of 1990, 4 species of hyperparasitoid have been found to account for most of the observed hyperparasitism of C. melanoscela in Ontario. These species are Gelis tenellus, G. apantelis (reported as G. buccalatrix in 1990 report), Eurytoma appendigaster, and Tritneptis scutellata (reported as Dibrachy cavus in 1990 report). A comparison of 3 methods of collection (cocoons under burlap strips, cocoons from natural branch surfaces and the sentinel method) revealed that the estimation of hyperparasitism was strongly influenced by the method of cocoon collection, presumably due to differences in hyperparasitoid search behaviour. The sentinel method in which host cocoons were placed on bark discs and fastened to a tree was most comparable to cocoons on natural branch

surfaces and provided the additional advantage of experimental control over seasonal variation in the density of available cocoons.

The sentinel method showed that in 1989, the weekly rate of hyperparasitism exceeded 40% for most of the year with maximum percent parasitism greater than 70% during mid to late July. The 1990 data are still being processed (cold storage requirements of some hyperparasitoids need to be satisfied before proceeding). But it is clear that hyperparasitoids are significant mortality factors for natural enemies of the gypsy moth and may limit the effectiveness of released parasitoids.

To examine the relative vulnerability of inundative release candidates to hyperparasitism, a bioassay protocol had to be developed. This was discussed in the 1990 OPAC research report. In 1990, a new candidate, the "halo" strain of C. melanoscela was screened. As its name suggests, this species has a distinctive silk "halo" around the cocoon which might render it less susceptible to hyperparasitoids. Behavioral studies in the laboratory indicated that smaller hyperparasitoids such as T. scutellata spend far less time ovipositing on "halo" cocoons than on normal and that even larger species, such as Gelis spp. spend relatively more time handling the "halo" cocoons. Thus, attacks on the "halo" cocoon would seem to require more time and may consequently mean that "halo" cocoons are less vulnerable to attack.

To test this hypothesis, the sentinel cocoon method was used in paired comparisons between "halo" and normal cocoons in the field. The results are preliminary because hyperparasitism in the cold-stored cocoons still must be assessed. At this time, however, there appears to be no significant difference in the rate of attack by hyperparasitoids on the two cocoon types. This leads to the conclusion that, despite observed differences in the handling time required by hyperparasitoids to successfully attack "halo" cocoons, this does not translate into differences in the rate of hyperparasitism in the field.

In 1991, there may be the opportunity to test another inundative release candidate available through a colleague at the USDA laboratory in Hamden, CT.

NORTHOVER, J., MCGARVEY, B.D., and WARNER, J.

Organic and modified programs for the control of apple scab.

Efficacy of plant oils against apple scab.

Plant or vegetable oils are glyceridic oils consisting of fatty acid substituted glycerol. They are structurally different from paraffinic oils used for control of arthropod pests. Some plant oils have been shown to be effective against blue mold (Peronospora tabacina) (Clayton et al., 1943) and powdery mildew (Sphaerotheca humuli) of hops (Martin and Salmon 1933). Against blue mold, oils rich in linoleic acid such as soybean oil were much more effective than oils low in linoleic acid such as olive and canola oils. Our experiments were conducted to examine the activity of several readily available plant oils for their activity against Venturia inaequalis, as possible alternatives to synthetic fungicides, as an organic, and sustainable approach to controlling apple scab.

In laboratory experiments employing McIntosh seedlings, several plant oils (0.95% w/w) emulsified with Agral 90 (0.05%) gave 68-89% protection when applied before the inoculation, but were ineffective when applied 1 day after inoculation. Five emulsified oils (olive, sunflower, canola, soybean and corn) as a group, were not significantly more effective then the Agral treatments alone (61% control), and were less effective than a captan treatment (100% control).

In a field experiment using four apple cultivars on M.26 rootstock, canola and soybean oils (0.95%) were emulsified with Agral 90 (0.05%) and applied as dilute sprays every 7-10 days, with 10 applications between 2 May and 13 July 1990. Foliage and fruit were evaluated for disease incidence 19-25 July. Emulsified canola and soybean oils reduced fruit infection from 64% to 9-15%, however Agral 90 alone was equally effective (16%). Captan was superior with only 2% fruit infection. The oil but not the Agral treatments resulted in fruit russetting of Golden Delicious and leaf spotting on Red Delicious and Empire, whereas McIntosh was little affected. Accidental overspraying of plot margins with adjacent treatments of captan and plant oil caused very severe fruit russetting of McIntosh and Empire fruits.

EBDC residues on apples following extended preharvest application intervals.

Ethylenebisdithiocarbamate (EBDC) fungicides such as mancozeb are essential for the control of apple scab which is the major disease of apples in eastern and central Canada. Without EBDC materials, and captan, the apple industry would be forced to rely on the newer sterol-inhibiting fungicides, which could fail after several years of overuse due to development of resistant strains of the apple scab fungus. With a view to minimizing residues on fruit at

harvest, an experiment was conducted in two locations in 1990 in which mancozeb applications were terminated at various extended preharvest intervals (PHI) instead of the previous PHI of 30 days. Each mancozeb application was made at a rate of 6 kg Dithane DG/ha using airblast sprayers. Preharvest intervals of 45, 76-77, and 112-118 days (petal fall) were found to give harvest residues on McIntosh apples of 0.47-1.25, 0.15-0.95 and 0.05-0.10 µg/g, respectively. These residues were well below the tolerance of 7 µg/g for mancozeb on apples. It is noteworthy that even 4-5 applications, made not later than petal fall (May 22-28), resulted in very low but nevertheless detectable residues at harvest in mid September.

SCHAAFSMA, A.W. and UNDERWOOD, J.A.

EVALUATION OF CANDIDATE LIQUID INSECTICIDES FOR THE CONTROL OF CORN ROOTWORMS WHEN APPLIED USING A SLOT INJECTOR TIMED TO WHEN THE LARVAE ARE ACTIVE.

MATERIALS: COUNTER 15G (terbufos), CGA 12223 500CS (isazophos), DI-SYSTON 15G and 720 LC (disulfoton), FORCE 1.5G and 50EC (tefluthrin), LORSBAN 480E and 15G (chlorpyrifos), and BASUDIN 500EC and 15G (diazinon).

METHODS: **Plot design.** Corn (Pioneer 3737) was planted using a John Deere Max-emerge planter at Parkhill on 8 May, at Ridgetown on 11 May and at Komoka on 15 May. Planting population was 64,000 seeds/ha in 0.75 m rows. Plots were double rows 11 m in length at Parkhill, 15 m at Komoka, and 20 m at Ridgetown, placed in a randomized complete block design with 4 replicates. There were 3 control plots per replicate and these were pooled in the ANOVA. The plots were fertilized and kept clean of weeds using commercially acceptable practices.

Application methods and equipment. Granular materials were applied using plot-scale Noble applicators which were bench-calibrated for each material. T-band applications were placed in a 15 cm band over the open seed-furrow.

Liquid insecticides were applied with a slot injector mounted on a 3-point hitch. On both sides of the row, a straight coulter, 3 mm thick and 44.5 cm in diameter, opened the slot and straight-stream nozzles (Teejet no.s 18, 24, 25, 31, 35, and 43) shot the liquid directly behind the coulter into the open slot. The coulter injector assembly was fully adjustable for depth of penetration and placement with respect to the centre of the corn rows. The injection solution was pressurized using a Imovilli Pumps model 50 pump capable of delivering a maximum of 3,800 kPa pressure. Pressure was adjusted through the use of a by-pass relief regulator. All hoses and fittings under pressure were of hydraulic quality and made of stainless steel. All insecticide rates are expressed as g ai /100 m of row.

Crop growth stages at injection time. The insecticides were injected at Ridgetown on 28 June at corn stage V5 for the carrier volume, distance from row centre placement, and application pressure tests, and on 3 and 4 July for the depth of penetration test at V5-6. The insecticide screening trials were applied on 4 and 5 July at V5-6 and V5 at Parkhill and Komoka, respectively. For the timing trial at Parkhill, the crop was at emergence, V3, V5, and V6 stages on 25 May, 11 June, 22 June and 5 July, respectively. For the timing trial at Komoka, the crop was at emergence, V2, V4, and V5 stages on 26 May, 11 June, 26 June and 6 July, respectively.

Damage assessments were made on 24 July, 9 Aug, and 2 Aug at Parkhill, Komoka, and Ridgetown, respectively. Four roots per plot were dug, washed and scored for root injury using the Iowa 1-6 root injury scale.

Yields were taken on 16 Nov, 19 Nov and 14 Nov at Parkhill, Komoka and Ridgetown, respectively. Yields were taken from the whole plot with a small-plot 2 row combine and corrected to 15.5 % moisture.

CONCLUSIONS: It was clear from these studies that injection applications need to be applied before the third week of June. Since the work on placement, carrier volume and application pressure was done after this time, the results are not conclusive. Based on the timing trials at Parkhill and Komoka (Table 1), both CGA-12223 500CS and FORCE 50EC showed considerable promise when applied before the third week of June. These applications were made at half the recommended rate of T-band applications made at planting. Note also that the very early injections were not as effective as those applied in the second and third week of June. These results show that there is potential for slot injection for the control of corn rootworm timed to when the larvae are active. Making slots 12.5 cm off the row centre up to 10 cm deep did not have a significant effect on corn growth. Slots 7.5 cm deep as close as 7.5 cm to the row centre also had no significant effect on yield.

Table 1. Effect of timed applications of liquid-formulated insecticides applied with a slot-injector on corn rootworm injury and yield of field corn. See text in methods for growth stages at injection time.

			Root Injury (Iowa 1-6)		Yield T/ha	Yield T/ha
Treatment	Rate (g ai/100m)	Applic. Date*	Parkhill	Komoka	Parkhill	Komoka
FORCE 50EC	0.6	25 May	2.55bc**	2.15b	6.634a	8.807ab
FORCE 50EC	0.6	11 Jun	2.03c	1.9b	6.096a	9.788ab
FORCE 50EC	0.6	26,22 Jun	2.28c	2.35b	6.012a	9.160ab
FORCE 50EC	0.6	6,5 Jul	3.8ab	2.35b	6.390a	8.884ab
COUNTER 15G	11.3	T-BAND	1.2c	2.4b	7.184a	10.140a
CHECK			3.94a	4.29a	5.715a	8.653b
CV %			31.6	33.9	16.9	10.19
DIAZINON 500E	5.6	25 May	3.53a	4.35a	6.575ab	8.744b
DIAZINON 500E	5.6	11 Jun	2.68a	4.45a	6.266ab	8.264b
DIAZINON 500E	5.6	26,22 Jun	2.28a	3.33ab	5.613b	9.505ab
DIAZINON 500E	5.6	6,5 Jul	3.1	4.03a	6.572ab	9.325ab
COUNTER 15G	11.3	T-BAND	1.2b	2.4b	7.184a	10.140a
CHECK			3.94a	4.29a	5.715a	8.653b
CV %			27.2	26.6	14.4	9.9
CGA-12223 500CS	2.75	25 May	2.78ab	3.53ab	6.337ab	9.102ab
CGA-12223 500CS	2.75	11 Jun	2.48b	4.20a	5.570b	9.293ab
CGA-12223 500CS	2.75	26,22 Jun	2.60b	1.88c	6.819ab	9.716ab
CGA-12223 500CS	2.75	6,5 Jul	3.33ab	3.45ab	6.596ab	8.246b
COUNTER 15G	11.3	T-BAND	1.2c	2.4bc	7.184a	10.140a
CHECK			3.94a	4.29a	5.715b	8.653b
CV %			29.3	28.8	14.7	10.7
DI-SYSTON 720LC	5.6	25 May	2.55abc	4.15a	6.261ab	8.976a
DI-SYSTON 720LC	5.6	11 Jun	2.33bc	3.53ab	6.562ab	8.678a
DI-SYSTON 720LC	5.6	26,22 Jun	2.93ab	4.23a	6.074ab	9.516a
DI-SYSTON 720LC	5.6	6,5 Jul	2.53abc	3.33ab	5.323b	8.728a
COUNTER 15G	11.3	T-BAND	1.2c	2.4b	7.184a	10.140a
CHECK			3.94a	4.29a	6.715ab	8.653a

CV%	33.1	25.0	16.4	12.5

*Application dates are listed for Parkhill, Komoka in that order.
**Values followed by the same letter are not significantly different at the 5 % level (Duncan's New Multiple Range Test) Comparisons can only be made within data blocks.

Smith, S.M. and Hubbes, M.

Management of the strawberry root weevil in ornamental tree nursery production using entomophagous nematodes.

Introduction:
In May of 1990, work was initiated on the study of the strawberry root weevil, Otiorhynchus ovatus (L) (Coleoptera: Curculionidae), at Somerville Nurseries, Inc. (Alliston, Ontario) and at the University of Toronto. The objectives of the study were to: 1) determine the life cycle of the strawberry root weevil under the climatic conditions of southern Ontario; 2) develop a predictive, non-destructive sampling technique; and 3) test strains of entomophagous nematodes for biological control of the strawberry root weevil.

To date, work has been carried out on all three objectives. Data on the life cycle of the strawberry root weevil was collected on the current generation of adult strawberry root weevil emerging from the soil between June and November 1990. Development of a non-destructive sampling technique was conducted concurrently with the life cycle study. Chemical insecticide trials were initiated in August and the data collected are currently being analyzed. The nematode trial will begin in the late spring of 1991, following bioassays run in the laboratory during the early spring of 1991.

Discussion of Preliminary Results:
Initially, 150 Colorado blue spruce trees (ca. 1 m high) were caged to study cohort development of the strawberry root weevil. In each of these cages, 15 adult weevils (all females) were released and allowed to oviposit under natural field conditions. Between June and November 1990, 23 of the trees within the cages were excavated and the soil around the base of the trees sieved to collect weevil populations. The study suggests that 15 adult female weevils can produce between 65 to 670 young larvae/tree. Oviposition data collected from adult females reared in the laboratory has indicated that adults can lay up to 150 eggs each. Oviposition begins about 4 weeks after adult emergence from the soil with ambient temperature affecting both the initiation and quantity of eggs laid. Of the three temperatures tested (25, 20, and 15°C), the coolest temperature appeared to be optimal for oviposition (greatest mean number of eggs and adult longevity).

Development of a non-destructive sampling technique was initiated in the summer of 1990. A soil core method was examined in relation to the total number of weevils present under each sample tree. Core samples (7 cm diameter by 14 cm length) were taken under 20 of the caged trees, prior to the excavation of the soil. From preliminary data, there appears to be a correlation between the number of larvae collected in the core samples to the total number of larvae excavated under the entire tree. Statistical tests have yet to be completed to determine the exact relationship in terms of sample depth and distance from the tree trunk.

Control trials using chemical insecticides have been completed. Results indicate that control of larval populations can be achieved using carbofuran but not diazinon. These results will be compared to the nematode trials planned for the spring of 1991. Statistical analysis of these chemical trials will be completed in the spring once all the data are available.

Schedule of Future Work:
Field work for the 1990 season has been completed. Larvae have also been collected for bioassays and for keying out different species of Otiorhynchus.

During the winter of 1991, samples of adult weevils will be processed (including measurement of weevil larval head capsules) and data analysis completed. Bioassays will also be carried out to identify the most suitable species/strain of nematode for the field trial to be run during the spring of 1991. The development of root weevil cohorts caged on individual spruce trees will be followed during the spring of 1991 until adult emergence is complete.

Souza Machado, V.

Integrated weed management systems with onions on Muck soils

I. 'Critical Period' of Weed Control Studies in Onions on Muck Soils

The 'critical period' of weed control in a crop, is the minimum period of time when weeds must be suppressed in order to prevent yield losses. Trials were run in 1989 and 1990 at the Muck Research Station in the Bradford Marsh, Ontario. In 1989 the onion cv. Aries was direct seeded on muck soils at a location selected for high weed pressure. Weed management involved hand weeding only. The main weed species were pigweed, potato weed and barnyard grass. The treatments involved two series, in which the plots were weed-free initially up to the 1, 2 or 3 leaf onion stage and later left weedy to harvest, and treatments in which the plots were left weedy up to the 1, 2, 3 or 4 leaf stage and later kept weed-free to harvest. The 'check' plot was handweeded throughout the onion growth period, up to harvest. Harvest results of onions indicated that treatments in the first series in which the plots were kept weed-free initially and weedy later, resulted in onion yields ranging from 1 to 25% of the weed-free 'check'. Treatments in the second series in which the plots were weedy up to the 1, 2, 3 or 4 leaf onion stage and later kept weed-free to harvest, resulted in yields of 100, 75, 23 and 2% of the weed-free 'check', respectively. These results suggested that the critical window for weed control begins at the 1 leaf stage of onion growth, under the field conditions tested in 1989.

Investigations in 1990 were therefore focused on the limits of this critical period, to determine when it ended. The onion cv. Aries was direct seeded in a high weed pressure site, with the main weed species being pigweed, potato weed and barnyard grass. The treatments involved maintaining 'weed-free windows' beginning at the 1 or 2 leaf stage of onion growth, with non-weeded periods before and after this window. Plots were therefore kept weed-free from 1 to 4, 5, 6, 7 and 8 onion leaf stage, as well as 2 to 5, 6, 7, and 8 onion leaf stage.

The results indicated that the treatments in which the plots were weed-free from 1 to 4, 5, 6, 7, or 8 onion leaf stage gave yields of 74, 89, 96, 100% of the weed-free 'check', respectively. The remaining treatments with weed-free periods commencing at the 2 leaf stage, resulted in lower yields ranging from 62 to 58% of the weed-free check. Studies to-date suggest that at the Bradford Marsh on high weed pressure sites, the 'critical period' of weed control in direct-seeded onions on muck soils, might be from the 1 to 6 leaf stage of onion development, under handweeded conditions. On sites with lower weed pressures, and where weed control is through the use of selective herbicides which do not disturb the soil weed bank, the 'critical period' window may be narrower and not as long as the 6 leaf stage.

II. Barley/Onion Interaction and Wind Erosion Control in Onions
Wind erosion with onions grown on muck soils is of concern to growers in the Bradford Marsh, Ontario. Spring sown barley was evaluated as a wind abatement barrier species to protect onion seedlings on muck soils, as well as its role in crop competition. Barley barriers were seeded as parallel rows between the onion rows and as broadcast seeding uniformly over the onion rows. Row seeding protects onion seedlings from anticlinal wind currents only, but broadcast seeding provides protection against winds from all direction as well as enhancing more effective root binding of the soil. Control of the competition status of the barley was by the application of the graminicides sethoxydim or fluazifop-p-butyl at 3 and 4 weeks after barley emergence (WAE). The onion cv 'Aries' and the barley cv 'Birka' was used. Sethoxydim was applied postemergence at 0.35 kg ai/ha and fluazifop-p-butyl at 0.25 kg ai/ha. In the check plots, barley was removed manually.

When the barley barrier was removed manually, 3 WAE, yields of both the proximal and distal onion rows were not significantly different from the corresponding onion rows in manual controlled check plots where the barley barrier was removed at emergence. Row barley controlled by application of the graminicide sethoxydim or fluazifop-p-butyl at 3 WAE indicated slight yield reductions of the proximal plot onion rows, whereas yield of the distal guard onion rows was not affected. However, in the broadcast barley trial yields of the plot as well as guard onion rows was severely reduced. Both graminicides seem to be equally effective in controlling barley at this stage. Graminicide application to row barley at 4 WAE registered significantly lower yields in the proximal rows as compared to manual removal of barley at emergence or at 3 WAE; the distal onion rows remained unaffected. Unlike the row barley treatments, broadcast barley killed with graminicides at 4 WAE resulted in almost total crop losses, as indicated by the low yield in both plot and guard onion rows. Compared to the no barley check plots, manual removal of the broadcast barley 4 and 5 WAE resulted in significant reduction of yield in all rows. In the broadcast seeding method, the spatial relationship between onions and the barley barrier was significantly altered and the competition between barley and onions was more intense earlier due to the spatial intimacy.

SUTTON, J.C. and PENG, G.

Biological control of grey mold In strawberries.

Our goal is to develop biocontrol as an alternative to fungicides for managing grey mold fruit rot caused by Botrytis cinerea. The approach is to identify microorganisms with strong antagonism against the pathogen, under a wide range of environmental conditions in strawberry plantings. Our studies focused on 1, evaluation of candidate organisms for fruit rot control; 2, population dynamics of leading candidates on strawberry plants; 3, biological suppression of spore production of the pathogen on strawberry leaves; and 4, development of methods for applying and timing applications of biocontrol agents.

Five candidate organisms selected in previous studies were evaluated in strawberry plots at the Arkell Research Station. Inocula of mycelial fungi (10^6 spores/ml) and of a white yeast (10^7 cells/ml) were applied to the strawberry plants with a compressed air sprayer at weekly intervals from the green-blossom bud stage to the white-pink fruit stage. Captan was applied at 6.75 kg/ha at the same times as a fungicide check. Spores of B. cinerea were added to all inocula and to captan at a final concentration of 2×10^3 conidia/ml at the second week of treatment only. All candidates except the white yeast suppressed fruit rot; Gliocladium roseum was as effective as captan. Relative effectiveness of the organisms was similar to that in 1989 (Table 1).

Table 1. Effects of biocontrol candidates and of captan on estimated incidence of grey mold fruit rot in field plots.

Treatment	Incidence of fruit rot (%) 1989	1990
Water (check)	71a*	44a
White yeast	72a	43a
Trichothecium roseum	41c	36b
Epicoccum nicrum	51c	35b
Trichoderma viride	43c	20c
Gliocladium roseum	56b	20c

*Cluster analysis, $P \leq 0.05$.

Population dynamics of our two most suppressive organisms, G. roseum and Penicillium sp., applied to the strawberry plants were monitored during six weekly periods of the crop season. About 10^4 propagules/strawberry leaflet were recovered at 7 days after each of the weekly applications. No clear effects of weather variables on G. roseum were identified.

Effectiveness of six organisms in suppressing sporulation of

B. cinerea on leaves colonized by B. cinerea was studied. In the greenhouse, biocontrol candidates were applied to the leaves 2 wk after they were inoculated with B. cinerea. Three days later, discs were cut from the leaves, incubated on paraquat-chloramphenicol agar (PCA), and later assessed for sporulation of the pathogen. In the field, leaflets of overwintered leaves were inoculated with biocontrol candidates on 26 May and 1 June (trial 1), or young leaves were inoculated with the pathogen on 13 May and with biocontrol organisms on 13 and 20 June (trial 2). Water and chlorothalonil 50 F (3.5 L product/ha) were used as checks. Discs were cut from the leaves 3 days after the last treatment in each trial and assessed for sporulation of B. cinerea on PCA.

Table 2. Effects of biocontrol candidates of chlorothalonil on sporulation of B. cinerea on strawberry leaves in the greenhouse and in the field.

Treatment	Number of conidiophores /leaf disc (greenhouse)	Incidence of sporulation on leaves in the field (%)	
		overwintered leaves	Young leaves
Water (check)	120a	25.7a	18.7a
Pink yeast	112a	27.0a	16.4a
Fusarium sp.	28b	23.0a	23.6a
Myrothecium verrucaria	2c	22.0a	14.0a
Trichoderma viride	4c	13.3b	2.8b
Penicillium sp.	3c	9.3b	0.0b
Gliocladium roseum	0c	10.7b	0.0b
Chlorothalonil	3c	9.0b	3.5b

Trichoderma viride, Penicillium sp. and G. roseum were as effective as chlorothalonil in suppressing spore production by the pathogen in strawberry leaves. These biocontrol agents and the fungicide were more effective in the field on young leaves than on old (overwintered) leaves.

Preliminary studies were done in which bees were used to apply G. roseum to strawberry flowers. Densities of the biocontrol agent on the flowers were more consistently high when delivered by bees than when applied weekly as inundative sprays. Fruit rot was suppressed to the same extent in the two treatments.

We conclude that our best biocontrol agents were at least as effective as fungicides in suppressing inoculum production of B. cinerea and grey mold fruit rot in strawberries, that populations of G. roseum are sustained reasonably well on strawberry, and that bees appear promising for delivering this biocontrol agent to strawberry flowers in the field.

Swanton, C.J., B.S. Clegg, Malik, V. and Michaels, T.E.

Integrated weed management in white beans.

In 1990 field and laboratory studies were conducted to develop a threshold management model for postemergence herbicide use in white beans and to compare the residual dissipation curves of metobromuron (Patoran) and bentazon (Basagran) in white beans grown under conventional management vs an integrated weed management system.

A season-long weed interference resulted in 37% less white bean yield as compared to the weed-free plots. Ragweed at all densities except, 2 and 4 ragweed m^{-2}, when allowed to compete with the whitebean from time of emergence, reduced white bean yield compared to season-long weed-free beans. However, the yields in ragweed infested plots were still significantly higher (36% higher on average) as compared to a season-long weed interference by a mixed weed population. Ragweed when allowed to compete with whitebeans after the second trifoliolate leaf emergence resulted in a significantly less yield. However, this adverse effect was only observed at very high ragweed densities of 16 and 32 weeds m^{-2}. The white bean yield was not affected by varying ragweed densities when weeds were allowed to compete with the crop after the initiation of flowering.

The residual dissipation of metobromuron and bentazon were analyzed in white beans grown under conventional management and an integrated weed management system. Metobromuron residues declined to below negligible levels (<0.1 ppm) 28 days after herbicide application at all dosages applied in both broadcast and banded herbicide treatments. However the residue level in the plant tissue appeared to be greater in the broadcast herbicide treatment compared to the banded treatments. Bentazon dissipated to negligible levels (<0.1 ppm) within 10 days of application in both management systems. No residues of either herbicide were detected in the beans at harvest.

TOMLIN, A.D., TU, C.M., and PROTZ, R.

The goals of this project are to measure the effects of herbicide treatments and cultivation, crop rotations, and tillage practices on soil microbiota (flora and fauna) and soil structure, using established plots on the fine-textured soils of the North Woodslee Field Station (Harrow Research Station) in Essex County.

Current cropping and tillage systems used in Ontario usually require substantial herbicide input for weed control. Reduced and zero-till methods may often require at least as much herbicide as is used for conventional till methods. The effect of continuous herbicide treatments (particularly under continuous soybean and corn rotation) on soil fauna and flora (soil's biotic component that is it significant contributor to soil's fine structure or microfabric) has not been investigated on Ontario foodlands. We propose measuring (1) soil microfaunal and (2) microfloral, and (3) soil physical properties (particularly porosity) in response to these treatments. Visual observations clearly indicated changes in soil structure (causing "soil stickiness" or "crusting") under continuous cropping with soybeans and corn. The Woodslee experimental site had been established for 8 years and consisted of 6 crop rotation regimens x 3 weed control methods (check, herbicide, hand cultivation) x 3 replicates (=54 plots).

An adjacent experimental site (96 plots) at Woodslee compares 4 herbicide treatments in conjunction with 3 tillage practices (light, medium and conventional) x 8 replicates in wheat/soybean rotations, providing an additional opportunity to compare tillage effects and herbicide treatments on soil biota and soil structure.

Soil textures and several important soil physical and chemical parameters were mapped at the site in 1990 to measure soil heterogeneity in preparation for subsequent analysis of soil faunal, floral and soil porosity measurements in relation to the main treatment effects (herbicide, crop rotation and cultivation). Both experimental sites were relatively homogeneous with no significant differences in soil organic matter, pH, or soil texture amongst the main treatment effects.

Soil cores, 15 cm deep (vertically split to compare for soil horizon effects) and replicated 3 times for each treatment were taken for microfloral and microfaunal analysis; earthworm samples were taken in June/July and again in early November of 1990 from both experimental sites at Woodslee. The cropping regimens tested at the long-term rotation site were as follows: continuous corn, continuous soybeans, alternating corn-soybean rotation, cereal-corn rotation, cereal-soybean rotation, and continuous cereal (these cropping regimes are all widely practised in southern Ontario).

The complex experimental design and replication of the plots we used (inherited) for these experiments meant that several hundred earthworm samples and soil cores had to be taken and analysed for their microfaunal and microfloral contents. As of January, 1991,

only the soil fauna had been analysed.

Microfloral tests will include plate counts, respiration, soil ATP, total biomass-carbon, nitrification, and Kjeldahl-N, and tests for soil enzymes. Porosity will be measured from impregnated soil blocks subjected to image analysis, and soil bulk density determinations.

The faunal results so far at both experimental sites show that hand cultivation for weed control significantly reduces earthworm biomass and abundance compared to herbicides for controlling weeds; the mechanical disturbance of topsoil by cultivation (hoeing) was more destructive to earthworm habitats than any direct or indirect toxic effects of herbicides, to earthworms. Earthworm numbers and biomass and free-living nematode numbers were significantly higher in cereal rotations than in continuous corn or soybean rotations. These effects could be a consequence of the more frequent cultivation and soil compaction from heavy equipment passes over these plots compared to cereal rotation plots. Continuous corn plots had significantly higher numbers of cryptostigmatid mites, which feed on decaying plant material (of which there was an abundance in these plots in the form of corn stover in the spring/summer sample. There were significant soil horizon effects, unrelated to any treatments; generally, in the spring/summer samples the upper soil horizon (0 to 7.5 cm) was dry and hot, and soil microfaunal numbers were lower than in the 7.5 to 15 cm deep horizon. By early November, when upper horizon soils were moister and cooler, the upper horizon harboured significantly higher densities of most soil fauna than the lower horizon. One consequence of these conditions was that in the spring/summer sample there were virtually, no earthworms extracted from any of the plots. Conventional tillage practice (mouldboard plough set at 20 to 25 cm deep), and shallow mouldboard ploughing (10 cm deep) caused significant reductions of Prostigmata and Cryptostigmata (soil mites), and Onychiuridae (springtails) numbers compared to shallow chisel ploughing. Again, these ploughing effects were larger than any induced by herbicide treatments, and were probably a result of disruption of topsoil habitat by the deeper ploughing.

Turgeon, J.J.; Chau, A.

Detection of flies infesting coniferous cones with colour traps.

The goal of this project is to develop traps to detect and monitor populations of flies infesting seed-cones of conifers in canadian seed orchards by assessing the response of the different species of flies to colours. Although four species of flies are found in Ontario our research has concentrated on one of the two species infesting tamarack cones, Strobilomyia laricis Michelsen. In the spring of 1989, a model of a trap capable of attracting males and females of S. laricis was discovered, but only at the end of the flight period. Thus, field tests to identified the preferred colour had to be repeated in 1990.

The response of S. laricis to colour traps was assessed in a natural stand of tamarack located on Highway 11, near Strickland, in Hagart Township, Ontario. Traps consisted of a plastic beer cup (Model T450, ca 400mL) with the sides covered with a sheet of Pantone (Letraset®). Twelve colours were tested: Yellow A, Opaque White A, Green A, Green 348A, Warm Red A, Rubine Red A, Rhodamine Red A, Purple A, Mauve 259 A, Pro Blue A, Reflex Blue A, Maroon 492 A. The traps were sprayed with Tangletrap® and two sets of the 12 colours were suspended in each of 5 trees; one set in the upper half and the other set in the lower half of the tree. These traps were installed on May 4. To identify the locations which detect the presence of the flies the soonest and the most consistently, we compared the trap captures of those placed on trees with those located at 5cm or 40cm above the ground (in an inverted position - bottom up), 1m or 5m away from the tree. These traps were the same as those suspended in the trees except the bottom of the cup was also covered with Pantone. They were installed on May 5. A third experiment aimed at comparing trap catches on the north and south side of the tree was not conducted.

Although more than 40 cm of snow fell to the ground between 10 May and 2 June, killing 99% of the tamarack cone crop, a total of 147 S. laricis flies were caught on the traps during a 5 week period. Most flies (especially the males) were caught during the first week. The colour Pro Blue A caught significantly more females than Yellow A, Green A and Green 348 A. The remaining colours did not differ from Pro Blue A. No significant differences were obtained for males, although Pro Blue A caught the highest number of males. The mean number of females caught in the lower and upper half of the tree were similar. Significantly more males were caught in the lower half than in the upper half of the trees. Traps located on the ground at either 1 or 5 m from the tree caught 13 flies over the same 5 week period suggesting that traps located in the tree are more effective in detecting the flies than traps away from the tree, at least with this model of trap.

All females caught during the first experiments were dissected. The first step was, for each female, to determine the stage of development of its oocysts. Based on morphological differences of

the oocysts, the oogenesis was divided into 10 stages. The second step consisted of crushing the bursa copulatrix of the female to determine whether the female had been mated. The final step was to dissect some cones at regular intervals to study the relationship between oocyst development and oviposition. This last step could not be carried out because of the high cone mortality due to the snow storm. Nevertheless it was found that both reproductively immature and mature females as well as mated and unmated females were found on the traps suspended in trees. Interestingly, the level of oocyst development and the mating status appear to influence the response of S. laricis to colours. This should be confirmed after data on the spectral reflectance of each colour are obtained later this month. If immature and mature flies are indeed attracted to different colours one should be able to develop a trap that would be more effective in detecting immature, unmated females to provide more time between trap catch and decision making (control action warranted or not).

Van Frankenhuyzen, K. and Cadogan B.L.

Optimization of pathogen-parasitoid interactions for integrated management of eastern spruce budworm, Choristoneura fumiferana.

The urgency of the budworm problem in the last 30 years has resulted in the adoption of a short-term control strategy by annual application of chemical or biological pesticides to protect current year foliage, without much consideration for long-term management of populations. Recent progress in spruce budworm research indicates the possibility of developing a population management strategy by integrating our knowledge of microbial control agents with that of the population biology of the budworm and its natural enemies. The main objective of our research was to develop the experimental basis for a population management strategy based on optimization of interactions between a budworm parasitoid, Apanteles fumiferanae, and the pathogen Bacillus thuringiensis (Bt).

We conducted a field trial to test two hypotheses. The first hypothesis was that the effectiveness of budworm parasitoids can be enhanced by delaying application of Bt. This hypothesis was based on laboratory observations that treatment with Bt killed parasitoids of early-instar budworm larvae by causing premature death of parasitized hosts, and that parasitoid mortality was minimized by delaying treatment to a later stage in budworm development because larval feeding rates declined as the parasitoid matured. Our results thus suggested that beneficial effects of parasitoids can be maximized by manipulating timing of Bt application. The second hypothesis was that delaying application of Bt maximizes debilitating effects of sublethal Bt doses on fitness of surviving larvae. That hypothesis was based on evidence from lab and field studies that exposure to Bt debilitates fitness of survivors by delaying development and by reducing pupal weight, adult emergence, and fecundity; that this debilitation depends on the instar exposed; and that it can contribute to population suppression in subsequent years. We thus postulated that a strategically-timed application of Bt can thus suppress budworm populations by enhancing effectiveness of larval parasitoids and debilitating fitness of surviving larvae.

The field trial was conducted near Black Sturgeon Lake in Northwestern Ontario. Population densities in this area were high (30-60 larvae/branch) with 25-30% parasitism of overwintering larvae. Dipel 352 (33.8 BIU/L) was applied at 30 BIU in 0.9 L/ha with a Cessna Ag Truck fitted with 4 Micronair AU4000 rotary atomizers. We used three 100 ha blocks. One was used as a control, one was sprayed at peak fourth instar, which coincided with onset of operational sprays ("regular timing"), and the other was sprayed 9 days later at peak fifth instar ("delayed timing").

Population reduction and foliage protection were assessed by cutting two 45cm branches from 60 balsam fir and 60 black spruce in each block before and after treatment. Pretreatment densities

ranged from 25 (black spruce) to 62 (balsam fir) larvae per branch. Delayed timing of application resulted in greater corrected population reductions (fir: 56%, spruce: 64%) than the regular timing (fir: 34%, spruce: 31%). Neither treatment resulted in significant foliage protection because of the high larval densities.

Parasitism by Apanteles fumiferanae was assessed by V. Nealis (FCOR).

Overwintering L_2's from each block were dissected to estimate incidence of parasitoids before spray application. The effect of spraying was evaluated by sampling 20 balsam fir in each treatment on two postspray dates and by determining parasitism from dissections of collected larvae plus counts of Apanteles cocoons on the foliage. Larval parasitism increased after spray application from 19% to 35% in the "regular" treatment and from 28% to 50% in the "delayed" treatment, whereas there was no increase in the control block. A survey of overwintering larvae will be conducted in the spring of 1991 to determine if the higher incidence of parasitoids in the 1990 generation is translated into a higher level of parasitism in the 1991 generation.

Dose acquisition by budworm larvae was examined by collecting 500 larvae from 20 branches collected 8,24,48,72, and 96 hours following spray application. Larvae were placed on artifical diet at 25°C for 4 days to determine their fate. The proportion of larvae that had ingested a lethal dose reached 50% in both spray blocks within 8 hours and did not exceed that level for the 4 days of monitoring. Only 5% and 7% of the larvae that had acquired a lethal dose were parasitized as compared with 20% and 40% of the surviving larvae in the "regular" and "delayed" treatment, respectively, confirming that parasitized larvae are less likely to acquire a lethal Bt dose.

The effect of treatment on fitness of survivors was examined by collecting pupae from the three blocks. Adults were permitted to emerge in mating cages and mating pairs from each treatment were placed in oviposition cages to monitor fecundity. Fertility of each female was determined as the ratio of unhatched eggs (after 10 days) to total eggs laid during a 7-day oviposition period. There was no significant difference between treatments in adult emergence, female fecundity, fertility, and adult size (winglength). We were thus unable to demonstrate any debilitating effects of Bt treatment on survivors. Laboratory experiments are underway to quantify the effect of sublethal Bt exposure on budworm performance under controlled conditions and to examine if timing of exposure affects the expression of sublethal effects.

Plans for 1991 include (1) continuation of laboratory experiments to quantify the relationship between ingested dose and sublethal effects, and (2) a possible repeat of the field experiment at intermediate population density to confirm the effect of timing on parasitoid incidence and to examine the trade-off between

population reduction and foliage protection when using a delayed timing for spray application.

APPENDIX IV

PUBLICATIONS RELATING TO THE ONTARIO PESTICIDES ADVISORY COMMITTEE RESEARCH PROGRAM, 1989-1990

A) RESEARCH

BOLAND, G.J. and Hunter, J.E. 1988

Influence of *Alternaria alternata* and *Cladosporium cladosporioides* on white mould of bean caused by *Sclerotinia sclerotiorum*. Can. Journal of Plant Pathology. 10:172-177.

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Survival time of unfed, first-instar western corn rootworm (Coleoptera: Chrysomelidae) and the effects of soil type, moisture, and compaction on their mobility in soil. Environmental Entomology.

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Epidemiology and management of *Botrytis* leaf blight of onion and grey mold of strawberry: a comparative analysis. Canadian Journal of Plant Pathology, (abstract).

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B) MISCELLANEOUS

BENDELL, J.F. and James, R.D. 1989.
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The role of sediment in metolachlor transport from agricultural fields', in Hadley, R.F. and E.D. Ongley (eds.), Sediment and the Environment (Proc. of the Baltimore Symposium, May 1989), International Association of Hydrological Sciences Publ. no 184, 11-18.

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Development of disparvirus, a nuclear polyhedrosis virus for control of gypsy moth in Ontario: reduced dosage and application volume. Agriculture Canada Biocontrol News 3:50-51.

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